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Decision-support quantitative models for valuing incentives in performance based contracts

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NAVAL POSTGRADUATE SCHOOL

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MBA PROFESSIONAL REPORT

Decision-Support Quantitative Models for Valuing Incentives in Performance Based Contracts

**By: Michael Aguilar,
George C. Estrada, and
Jeffrey J. Myers
June 2005**

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**DECISION-SUPPORT QUANTITATIVE MODELS FOR VALUING
INCENTIVES IN PERFORMANCE BASED CONTRACTS**

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

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DECISION-SUPPORT QUANTITATIVE MODELS FOR VALUING INCENTIVES IN A PERFORMANCE BASED CONTRACTS

ABSTRACT

The purpose of this MBA project is to identify the actual cost savings when a Performance Based Logistics (PBL) contract, with incentives, is awarded to replace a specified maintenance echelon for critical components or subcomponents of systems. We will examine the impact on system availability to determine if a proposed investment will be practical. The entire logistics flow and maintenance processes, to include all associated sub-activities, will be analyzed. In order to do this, we must initially identify all costs of operating the current organic maintenance echelon, which will become the PBL baseline. This will be used to determine the value added of any incremental percentage change in readiness or elimination of organic maintenance echelon(s). We propose to develop a simulation based decision support tool to assist Program Managers (PM) with issues of valuing options for the improvement of system availability, and making appropriate investment options. Ultimately, this project will determine the financial viability and practicality of implementing a PBL incentive contract.

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TABLE OF CONTENTS

I.	INTRODUCTION	1
A.	BACKGROUND	1
B.	PURPOSE.....	4
C.	RESEARCH QUESTION	4
D.	SCOPE AND METHODOLOGY	4
1.	Scope.....	4
2.	Methodology	5
E.	ORGANIZATION OF STUDY	5
II.	BACKGROUND	7
A.	NAVAL AVIATION MAINTENANCE PROGRAM.....	7
1.	Performance Improvement	8
2.	Three Levels of Maintenance	9
a.	<i>Organizational Level Maintenance</i>	<i>10</i>
b.	<i>Intermediate Level Maintenance.....</i>	<i>11</i>
c.	<i>Depot Level Maintenance</i>	<i>11</i>
3.	Maintenance Types	12
B.	PERFORMANCE BASED LOGISTICS.....	12
1.	Introduction.....	12
2.	Background	13
a.	<i>Performance Based Logistics within Department of Defense</i>	<i>13</i>
b.	<i>Navy Performance Based Logistics.....</i>	<i>14</i>
C.	F/A-18E/F INTEGRATED READINESS SUPPORT TEAM (FIRST) PROGRAM	15
1.	General.....	15
2.	FIRST Program Structure.....	15
4.	NAVAIR and NAVICP Business Case Analysis	16
5.	Actual Cost of FIRST Program as of August 2004.....	17
III.	METHODOLOGY	21
A.	BASELINE	21
B.	MODELS	21
C.	DATA GATHERING	23
D.	ASSUMPTIONS.....	23
E.	LIMITATIONS	24
1.	Limitations of the LCC Models	24
2.	Limitations of the Simulation Model	25
F.	APPLICATION.....	25
IV.	SCENARIO DISCUSSION AND ANALYSIS	27
A.	SCENARIO ONE.....	28
1.	Scenario One Decision Support Tool Description.....	29

2.	Spreadsheet Decision Support Tool Application	30
a.	<i>Traditional Maintenance Level Activities in Regards to Cost</i>	<i>30</i>
b.	<i>The Effect on LCC by Eliminating I-Level Maintenance Activities</i>	<i>30</i>
3.	Scenario One Model Analysis	31
a.	Scenario 1-a LCC Spreadsheet Model Analysis	31
b.	Scenario 1-a Conclusion.....	32
c.	Scenario 1-b LCC Spreadsheet Model Analysis	33
d.	Scenario 1-b Conclusion.....	33
B.	SCENARIO TWO.....	36
1.	Scenario Two Decision Support Tool Analysis	38
2.	Spreadsheet Decision Support Tool Application	38
a.	<i>Traditional Maintenance Level Activities in Regards to Cost</i>	<i>38</i>
b.	<i>The Affect on LCC by Outsourcing I Level Maintenance Activity for a Single Critical Component</i>	<i>39</i>
c.	<i>The Affect on LCC by Outsourcing I-Level Maintenance Activity</i>	<i>40</i>
3.	Scenario Two Model Analysis.....	41
a.	Scenario 2-a LCC Spreadsheet Model Analysis	41
b.	Scenario 2-a Conclusion.....	44
c.	Scenario 2-b LCC Spreadsheet Model Analysis	44
d.	Scenario 2-b Conclusion.....	46
C.	SCENARIO THREE	47
1.	Decision Support Tool Description	48
2.	Spreadsheet Decision Support Tool Application	48
a.	<i>PM and Contracts</i>	<i>48</i>
b.	<i>The Effect on LCC by Outsourcing Organic I-Level Maintenance.....</i>	<i>49</i>
c.	<i>Contractor Incentive to Improve MTBF Through Redesign</i>	<i>50</i>
3.	Simulation Decision Support Tool Application.....	51
a.	<i>PM and Warfighter</i>	<i>51</i>
b.	<i>The Effect on Operational Availability by Outsourcing Organic I-Level Maintenance</i>	<i>51</i>
4.	Scenario Three Model Analysis	52
a.	Scenario 3-a LCC Spreadsheet and Simulation Model Analysis.....	52
b.	Scenario 3-a Conclusion.....	53
c.	Scenario 3-b Spreadsheet Model Analysis	53
d.	Scenario 3-b Conclusion.....	54
V.	CONCLUSSION AND RECOMMENDATIONS.....	55
A.	MOTIVATION	55
B.	OVERVIEW.....	56

C.	CONCLUSIONS	58
D.	RECOMMENDATIONS.....	59
APPENDIX A.	UAV SYSTEM DESCRIPTION.....	61
APPENDIX B.	LIST OF FIGURES	69
APPENDIX C.	LIST OF ABBREVIATIONS AND ACRONYMS	87
LIST OF REFERENCES	91
INITIAL DISTRIBUTION LIST	93

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LIST OF FIGURES

Figure 1. Baseline Scenario (User Inputs Page).....35

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LIST OF TABLES

Table 1.	Estimation of Cost Avoidance for FIRST Program Contract	17
Table 2.	IG DoD-Corrected FIRST Program Savings	19
Table 3.	Scenario Quick Reference Guide	27

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-Captain Michael Aguilar

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-Lieutenant Jeffrey Myers

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-Lieutenant Commander, George C. Estrada

I. INTRODUCTION

A. BACKGROUND

For years the Department of Defense (DoD) has been plagued with legacy system support for aging weapon systems that are in use far longer than they were ever designed. Costs for weapon systems that had far outlived their original life estimate reached an all time high in 1998. The DoD calculated that annually it spends about \$59 billion on logistics support to operate and sustain weapon systems.¹ Beginning in FY 1998, in response to DoD direction, the services began implementing logistics support strategies that rely on the private sector to provide most of the support that the government traditionally provided.² A number of logistics support strategies were undertaken all designed to transform its logistics infrastructure. The specifics of each initiative were centered on a few key elements. The most important elements are to reduce total life-cycle cost of the program and improve customer support. The best way to accomplish these two elements was to focus on the reliability, maintainability, availability and affordability of spare parts.

Traditionally, product acquisition and sustainment acquisition have been separate and not necessarily equal concerns.³ This type of thinking has led to an environment that creates significant supportability issues within weapons programs that typically span decades. For the government to maximize performance for the life of the system then the traditional way of looking at acquisition must change to a system that looks at logistics up front and early within the acquisition cycle. This is especially true since it has been estimated that about 30 percent of all dollars spent are used to acquire the system, while the remaining 70 percent of all dollars are used for support.⁴

¹ GAO Report No. GAO-01-23, "Prices of Navy Aviation Spare Parts Have Increased," November 6, 2000.

² Department of Defense Office of the Inspector General Report No. D-2003-120, "F/A-18 E/F Integrated Readiness Support Teaming Program," August 8, 2003.

³ Berkowitz Gupta Simpson and McWilliams (Dec 2004-Mar2005). "Defining and Implementing Performance-Based Logistics in Government", Defense AR Journal, Fort Belvoir, V. 11(3) pp.254-268.

⁴ Ibid

Understanding that there was a need for an improved acquisition strategy the Department of Defense introduced Performance Based Service Acquisition under the Defense Acquisition Reform of 2000. The guiding principle is if an outside contractor can provide a service to the government more effectively than it can be obtained within the service (organically) then the government should enter into contract with them. Instead of providing requirements to be met in the form of specifications the government should only spell out the desired outcome in the form of a performance measurement. This process allows the contractor to determine the best way to accomplish the task. This process often times leads to a reduction in cost and product innovations.

Performance Based Logistics is an extension of Performance Based Service Acquisition with a focus on the complete logistics service for weapon systems. The current manual that DoD uses as a guide is called Performance-Based Logistics: A Program Manager's Product Support Guide.

This guide defines PBL as:

Performance-Based Logistics (PBL) is the preferred Department of Defense product support strategy to improve weapon system readiness by procuring performance, which capitalizes on integrated logistics chains and public/private partnerships. The cornerstone of PBL is the purchase of weapon system sustainment as an affordable, integrated package, based on output measures such as weapon system availability, rather than input measures, such as parts and technical services. The Quadrennial Defense Review (QDR) and the Defense Planning Guidance (DPG) directed the application of PBL to new and legacy weapon systems. PBL Implementation is also mandated by [DoD Directive 5000.1](#)

This guidebook, commonly referred to as the "PBL Guidebook", was recently released in November 2004 and was developed as a result of the lessons learned from existing Department of Defense PBL programs. The first PBL guidebook was released three years earlier and contained far less specifics on how Program Managers (PM's) should implement PBL and how they should develop PBL strategies for their Program Office. The new guidebook provides all the necessary references and links to the most recent DoD directives, associated instructions and regulations that PM's will need. It clearly lays out PBL and provides the necessary tools to the PM on what steps are necessary for implementing and asses PBL within DoD Program Offices. However, that

was not the case when the services began implementing logistics support strategies that relied on private sector to provide most of the support that the Government traditionally provided.

One well documented case is the Navy's initiative with Boeing Company (Boeing) to manage the initial purchase and replenishment of 519 repairable parts and 5,856 consumable parts for the F/A-18E/F aircraft. The PBL initiative was called F/A-18E/F Integrated Readiness Support Teaming Program (FIRST) which was signed on May 9, 2001. The five year contract was designed to be a one stop shop for the Program Manager. Never before had this type of contract at this magnitude been undertaken. The Business Case Analysis that was used to justify the contract award claimed that Boeing would save the U.S. Navy \$1.4 billion over 30 years, reduce turn around time (TAT) from 60 days to 45 days on repairs, and increase aircraft reliability (flight time between unscheduled removals) by 10 percent.⁵ However, these claims have proven to be inaccurate.

The Department of Defense Office of the Inspector General published a report dated August 8, 2003 discussing the initiative with Boeing. The report concluded "The Navy BCA used to justify the award of the FIRST contract over stated the cost of DoD performance."⁶ As a result the FIRST program is estimated to cost \$ 142.8 million⁷ more than traditional support would have cost if the contract was not entered into.

Performance-Based Logistics has been mandated by the Department of Defense in the Quadrennial Defense Review (QDR), Joint Vision 2020 and is here to stay. The current PBL Guidebook clearly lays out PBL and provides the necessary tools to the PM on what steps are necessary for implementing PBL within DoD Program Offices but still lacks a proven methodology for determining costs of organic support. This leads to a clear problem across the services on how to accurately determine what the actual cost of organic maintenance support is. Clearly the FIRST Program has many lessons that can be learned and applied to future PBL incentives. But until a methodology is developed to

⁵ Department of Defense Office of the Inspector General Report No. D-2003-120, "F/A-18 E/F Integrated Readiness Support Teaming Program," August 8, 2003.

⁶ Ibid, pg 4

⁷ Ibid

actually determine cost savings it will be nearly impossible to know what incentives are worth under a PBL contract.

B. PURPOSE

Develop a simulation based decision support tool to assist Program Managers (PM) with issues of valuing options for the improvement of system availability, and making appropriate investment options. This tool will be used to identify the actual cost savings when a Performance Based Logistics (PBL) contract, with incentives, is awarded to replace a specified maintenance echelon for critical components or subcomponents of systems. This research will examine the impact on system availability to determine if a proposed investment will be practical. The entire logistics flow and maintenance processes, to include all associated sub-activities, will be analyzed. In order to do this, we must initially identify all costs of operating the current organic maintenance echelon, which will become the PBL baseline. This will be used to determine the value added of any incremental percentage change in readiness or elimination of organic maintenance echelon(s). Ultimately, this research project will determine the financial viability and practicality of implementing a PBL incentive contract.

C. RESEARCH QUESTION

Since there is no standard DoD Total Life Cycle Cost Model that can determine the costs associated with PBL incentives, how can program managers accurately compute the value additive (i.e., in terms of dollars and Operational Availability (Ao)) when sub-component reliabilities or logistics support elements change?

D. SCOPE AND METHODOLOGY

1. Scope

This report focuses on the affect, in terms of dollars and Operational Availability (Ao), when assessing the potential application of a PBL strategy. Three realistic PBL scenarios were developed and analyzed with focus primarily on cost savings and Ao.

Each scenario examines the affect on Life Cycle Cost (LCC) and or Ao when the PBL strategy is to:

1. Outsource an organic (i.e., Operational (O-level), Intermediate (I-level) or Depot (D-level) maintenance echelon.
2. Incentivize the contractor to improve the Mean Time Between Failure (MTBF) through redesign of the system, subsystem, or major assembly level.
3. Reduce the Turn Around Time (TAT) (i.e., total time it takes for the part to return to the system once removed).

2. Methodology

This project developed and used an Arena simulation based model, and two Microsoft Excel flexible Total Life Cycle Cost Models that can compute the value additive (i.e. in terms of dollars and Ao) when sub-component reliabilities or logistics support elements change. Each scenario began with a baseline which became the standard throughout the research project. The U.S. Army's Unmanned Aerial Vehicle (UAV) Shadow System was used to populate the models. Quantitative data was assumed for MTBF and price per item. However, each scenario used the same assumed data. The Arena simulation model was used to reflect the contribution of an incremental increase in MTBF to the system's Ao. The Excel model was used to reflect the financial justification to determine the value of improved reliability. Each scenario was analyzed and compared to the baseline to determine the point of diminishing returns for investing in the improvement of reliability.

E. ORGANIZATION OF STUDY

This report is organized into five chapters. Chapter II includes literature reviews on Naval Aviation Maintenance, PBL and the Boeing FIRST contract. Chapter III discusses the Excel TLCC model and the Arena simulation model and their potential as a PM decision support tool. Chapter IV analyzes the three PBL scenarios and discusses the findings. Chapter V offers our overall conclusions and recommendations.

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II. BACKGROUND

A. NAVAL AVIATION MAINTENANCE PROGRAM

To fully understand the PBL scenarios it is necessary to understand the Naval Aviation Maintenance Program (NAMP), performance improvement and the seven performance elements, the three levels of maintenance and the type of maintenance that is done at each level. These paragraphs are excerpts from the recently released Commander Naval Air Force (COMNAVAIRFOR) Instruction 4790.2 Volume I, dated 1 February 2005.

The objective of the NAMP is to achieve and continually improve material readiness and safety standards established by the Chief of Naval Operations (CNO)/COMNAVAIRFOR, with coordination from the Commandant of the Marine Corp, with optimum use of manpower, material, and funds. COMNAVAIRFOR aviation material readiness standards include:

- Repair of aeronautical equipment and material at that level of maintenance which ensures optimum economic use of resources.
- Protection of weapon systems from corrosive elements through the prosecution of an active corrosion control program.
- Application of a systematic planned maintenance program and the collection, analysis, and use of data in order to effectively improve material condition and safety.

The methodology for achieving the spirit and intent of the NAMP objective is labeled “performance improvements.” New or improved cost effective capabilities and processes must be continuously pursued. Mutually supporting teamwork, constant communication, and compatible measures are critical elements for success. Performance improvements must be targeted to accomplish the following broad goals:

- Increased readiness.

- Improved quality.
- Improved deployability.
- Improved sustainability.
- Reduced Costs.
- Enhanced preparedness for mobilization, deployability, and contingency operations.
- Enhanced supply availability
- Improved morale and retention
- Compliance with environmental laws, rules, and regulations.

1. Performance Improvement

To realize continuous gains, performance improvements must be fully understood and actively managed. As new techniques and concepts evolve, they must be evaluated and then implemented if found to be sound. Before performance improvements can be successfully managed, all performance elements must be defined. The seven performance elements are defined as follows:

- Productivity – The pivotal element of the seven performance elements in that it is highly interrelated with all the elements. Productivity must always be viewed in terms of its impact on effectiveness, efficiency, quality, innovation, quality of work life, and budgetability. Productivity relates the outputs created by a system to the inputs required to create those outputs, as well as the transformation process of inputs to outputs. Inputs in the form of personnel, skills, material, Ready for Issue (RFI) and non-RFI components, bit and piece parts, equipment, Support Equipment (SE), hand tools, methods, technical publications, directives, data, environment, facilities, funding, and energy are brought into the system. These inputs are transformed into outputs (i.e., Ready for Tasking aircraft, RFI components, manufactured goods, inspection and calibration services) which are vital in providing necessary

maintenance and logistic support to achieve and sustain naval aircraft readiness.

- Effectiveness – A function of the outputs, tells us how well goals are achieved. For example, in Intermediate Maintenance Activities (IMA's) it is how well we repair the right things at the right time to ensure maximum readiness is achieved. In squadrons, it is how well assigned aircraft can perform their mission.
- Efficiency – The relationship between actual and planned resources. Efficiency describes how well the resources were used, as in manpower utilization.
- Quality – The degree of satisfaction in a product or service as determined by the customer. Fit, form, function, reliability, maintainability, consistency, and uniformity are some characteristics affected by quality.
- Innovation – The creativity applied to the transformation process, for example, development of new repair processes.
- Quality of Work Life – A function of morale and other factors which affect personnel pride and motivation.
- Budgetability – The ability to perform the assigned mission within allotted resources.

2. Three Levels of Maintenance

The NAMP is founded upon the three-level maintenance concept and is the authority governing management of O-level, I-level, and D-level aviation maintenance. It provides the management tools required for efficient and economical use of personnel and material resources in performing maintenance. It also provides the basis for establishing standard organizations, procedures, and responsibilities for the accomplishment of all maintenance on naval aircraft, associated material, and equipment. Dividing maintenance into three levels allows management to:

- Classify maintenance functions by level.
- Assign responsibilities for maintenance functions to a specific level.
- Assign maintenance tasks consistent with the complexity, depth, scope, and range of work to be performed.
- Accomplish any particular maintenance task or support service at a level which ensures optimum economic use of resources.
- Collect, analyze, and use data to assist all levels of NAMP management.

a. Organizational Level Maintenance

O-level maintenance is performed by an operating unit on a day-to-day basis in support of its own operations. The O-level maintenance mission is to maintain assigned aircraft and aeronautical equipment in a full mission capable status while continually improving the local maintenance process. While O-level maintenance may be done by I-level or D-level activities, O-level maintenance is usually accomplished by maintenance personnel assigned to aircraft reporting custodians. O-level maintenance functions generally can be grouped under the category of:

- Inspections.
- Servicing.
- Handling.
- On equipment corrective and preventative maintenance. (i.e., on-equipment repair, removal, and replacement of defective components.)
- Incorporation of Technical Directives (TDs), less SE, within prescribed limitations.
- Record keeping and reports preparation.
- Age Exploration (AE) of aircraft and equipment under Reliability Centered Maintenance (RCM).

b. Intermediate Level Maintenance

The I-level maintenance mission is to enhance and sustain the combat readiness and mission capability of supported activities by providing quality and timely material support at the nearest location with the lowest practical resource expenditure. I-level maintenance consists of on and off equipment material support and may be grouped as follows:

- Performance of maintenance on aeronautical components and related SE.
- Field Cognizant Activities (FCAs), which perform I-level calibration of designated equipment.
- Processing aircraft components from stricken aircraft.
- Incorporation of TDs.
- Manufacture of selected aeronautical components, liquids and gases.
- Performance of on-aircraft maintenance when required.
- AE of aircraft and equipment under RCM.

c. Depot Level Maintenance

D-level maintenance is performed at or by naval activities industrial establishments to ensure continued flying integrity of airframes and flight systems during subsequent operation service periods. D-level maintenance is also performed on material requiring major overhaul or rebuilding of parts, assemblies, subassemblies, and end items. It includes manufacturing parts, modifying, testing, inspecting, sampling, and reclaiming. D-level maintenance supports O-level and I-level maintenance by providing engineering assistance and performing maintenance beyond their capabilities. D-level maintenance functions may be grouped as follows:

- Aircraft Standard Depot Level Maintenance (SDLM) (standard and rework)
- Rework and repair of engines, components and SE.
- Calibration by Navy calibration laboratories and Navy Standard Primary Laboratories.

- Incorporation of TDs.
- Modification of aircraft, engines, and SE.
- Technical and engineering assistance by field teams.
- AE of aircraft and equipment under RCM.

3. Maintenance Types

Rework and upkeep are the two types of aircraft maintenance performed within the naval establishment without distinction as to levels of maintenance.

- Rework – Rework may be performed on aircraft or equipment. It is performed by industrial type activities assigned the mission, task, or functional responsibility of providing maintenance program support. Rework is performed with military and civilian personnel and managed by Commander Naval Air Systems Command.
- Upkeep – Upkeep is performed on aircraft or equipment. It is performed by military and contractor personnel and is managed by the Aircraft Controlling Custodians (ACCs).

B. PERFORMANCE BASED LOGISTICS

1. Introduction

The PBL approach is the preferred product support strategy within the DoD. The DoD is implementing PBL in both new acquisition programs and legacy programs. All Services are executing PBL policy at the system, subsystem, and component level. The services are also working in conjunction with each other to implement PBL on joint programs. Performance based logistics provides the logistic manager a way to increase reliability, reduce logistical footprint and save the services money on Total Life Cycle Costs.

2. Background

a. *Performance Based Logistics within Department of Defense*

Implementation of PBL was mandated in September, 2001 in the Quadrennial Defense Review, and initial guidance was issued by the Office of the Secretary of Defense (OSD).⁸ The OSD issued a Product Support Guide that provided a strategy for executing PBL.⁹ Subsequently, each of the Services provided implementation guidance to their programs.¹⁰ In accordance with the Fiscal Year 2003 Defense Policy Guidance, the scope of the programs to be considered for PBL implementation included all new systems and all Acquisition Category (ACAT) I and II fielded systems.¹¹ The importance of sustainment in the program life cycle and in implementing PBL was recognized. To ensure the requisite priority on sustainment issues within program offices and to ease PBL implementation efforts, the concept of Total Life Cycle Systems Management (TLCSM) was promulgated.¹²

Total Life Cycle Systems Management emphasizes an early focus on sustainment in the program management office, making the PM responsible for all activities associated with the acquisition, development, production, fielding, sustainment, and disposal of a weapon system across its life cycle. This was a significant paradigm shift from traditional program management that focused on the early phases (i.e., acquisition, development, fielding) of the life cycle.¹³ To support the decision-making process in selecting organic and commercial support providers, OSD promulgated guidelines for

⁸ Aldridge, E. C. (2002, February 18). Performance-Based Logistics. Washington, DC: Under Secretary of Defense (Acquisition, Technology, and Logistics).

⁹ Morales, D. K. (2001, November 6). Product Support guide. Washington, DC: Deputy Under Secretary of Defense (Acquisition, Technology, and Logistics).

¹⁰ Bolton, C. M. (2002, April 1). Army implementation of Performance-Based Logistics (PBL). Washington, DC: Assistant Secretary of the Army (Acquisition, Technology, and Logistics).

Schnieder, P. A. (2002, April 26). Department of the Navy Performance-Based Logistics (PBL) implementation plan. Washington, DC: Assistant Secretary of the Navy (Acquisition, Technology, and Logistics).

¹¹ Young, J. J., Jr. (2003, January 27). Performance-Based Logistics (PBL) guidance document. Washington, DC: Assistant Secretary of the Navy (Research, Development and Acquisition).

¹² Aldridge, E. C. (2003, March 7). Total life cycle system management and performance-based logistics. Washington, DC: Under Secretary of Defense (Acquisition, Technology, and Logistics).

¹³ Devries, H. J (Dec 2004-Mar2005). "Performance-Based Logistic-Barriers and Enablers to Effective Implementation", Defense AR Journal, Fort Belvoir, V. 11(3) pp.242-254.

conducting BCA.¹⁴ In addressing the performance metrics' relationship to desired outcomes, OSD provided some common examples such as Ao and logistics footprint.¹⁵

b. Navy Performance Based Logistics

As a result of DoD direction, the Naval Inventory Control Point, Philadelphia has established a "performance-based" logistics program to meet the Naval Supply systems Command assigned goal for improving support, reducing infrastructure, and lowering the Navy's weapon systems cost of ownership.¹⁶ During 2001 and 2002 the Government Accountability Office (GAO) released two separate reports that addressed the rising costs of Navy aviation spare parts.

Specifically, GAO reported that the prices customers paid for Navy-managed parts had increased on average 12 percent from FY 1994 through FY 1999 and continued to rise on average 37 percent from FY1999 through FY 2002 for three of the Navy's weapon system, the H-53 helicopter, the F/A-18, and AV-8B aircraft and their engines¹⁷

The Navy had been well aware that there were issues with average costs increasing. Once DoD began to encourage Performance Based Acquisition the Navy quickly began evaluating different support solutions. The Naval Air (NAVAIR) Program Office's were looking at innovative ways to reduce the total ownership costs while meeting the Chief of Naval Operations readiness goals. The NAVAIR F/A-18 Program Office established an overall goal to reduce F/A-18 E/F weapon system ownership costs by 20 percent and evaluated options for a total support solution.¹⁸ As part of the evaluation, NAVAIR performed a Trade Study Cost Analysis which was released in July of 1999. This analysis looked at a teaming option with Boeing Aircraft who is the prime vendor for the F/A-18 aircraft. This teaming arrangement is referred as the F/A-18E/F Integrated Readiness Support Teaming (FIRST) Program. On May 9, 2001 NAVICP awarded

¹⁴ Wynne, M. N. (2004a, January 23). Performance-Based Logistics (PBL) Business Case Analysis (BCA). Washington, DC: Under Secretary of Defense (Acquisition, Technology, and Logistics).

¹⁵ Wynne, M. N. (2004b, August 16). Performance-Based Logistics: Purchasing using performance-based criteria. Washington, DC: Under Secretary of Defense (Acquisition, Technology, and Logistics).

¹⁶ Department of Defense Office of the Inspector General Report No. D-2003-120, "F/A-18 E/F Integrated Readiness Support Teaming Program," August 8, 2003.

¹⁷ Ibid

¹⁸ Ibid

Boeing a 5-year requirements-type contract that established the Navy teaming arrangement with Boeing. One year later the Navy had awarded 51 aviation performance-based logistics contracts under the program and had another 45 systems/items under evaluation.¹⁹

C. F/A-18E/F INTEGRATED READINESS SUPPORT TEAM (FIRST) PROGRAM

1. General

The FIRST contract creates a teaming arrangement between industry and the United States Government to improve parts availability and aircraft reliability for the F/A-18 E/F Super Hornet, with the overall goal of reducing Total Ownership Cost (TOC). The primary methods for accomplishing this will be continuous logistics processing with reliability and maintainability improvements. Boeing has management authority to meet system demand requirements, improve system/parts reliability and availability, and manage obsolescence. Boeing is to independently manage a total logistics support program for the F/A-18 E/F. Financial incentives are provided for innovation and efficiency to reduce the F/A-18 E/F TLCC. This performance concept anticipates both logistics performance enhancements and cost of ownership benefits by leveraging proven commercial support concepts.²⁰

2. FIRST Program Structure

The FIRST Program contract was a 5-year requirements-type contract with a 2-year base period and included three successive 1-year price ceiling priced options. The base period was a cost-plus-incentive-fee type contract with award fee provision based on performance requirements.²¹ The contract was designed to be a one stop shop for the Program Manager. Never before had this type of contract at this magnitude been undertaken. Boeing was contracted to not only procure the initial and replenishment of 519 repairable parts and 5,856 consumable parts but to repair them as well.

The contract gives Boeing responsibility for the support process for parts particular to the F/A-18E/F aircraft including responsibility for meeting

¹⁹ Ibid

²⁰ FIRST Contract, N00383-01-D-001H, 04 May 2001.

²¹ Ibid

demand requirements, improving system and parts reliability and availability, and managing obsolescence. Boeing also became the supply chain manager for those parts, including forecasting, parts management, transportation, distribution, and warehousing.²²

Additionally, Boeing subcontracted the majority of the repair work to the Naval Aviation Depot (North Island) so as to not be in violation of 2464, title 10, United States Code.

4. NAVAIR and NAVICP Business Case Analysis

Both NAVAIR and NAVICP performed business case analysis (BCA) to justify the teaming venture with Boeing. In June 1999, NAVAIR prepared a BCA outlining the benefits that DoD would derive from the proposed teaming with Boeing. The BCA compared the cost avoidance in seven different areas to the costs that would be incurred under the current organic system. The BCA projected that the FIRST Program would:

- Provide a total logistics cost avoidance of \$1.4 billion over 30 years,
- Reduce turnaround time from 60 days to 45 days on repairs, and
- Increase aircraft reliability (flight time between unscheduled removals) by 10 percent.²³

The majority of the cost avoidance was centered in two areas of the seven that were analyzed. These areas were support equipment and supply support which represented 75 percent of the \$1.4 billion.

Since Boeing had agreed to become the supply chain manager, to include parts management, transportation, distribution, and warehousing, then there should be a significant savings to the Navy Working Capital Fund (NWCF). To assist in determining what the savings might be NAVICP was asked to provide their own BCA over the 5-year contract that addressed costs associated with the supply support element. Since NAVICP had not performed a BCA examining the costs associated with the supply support element a integrated process team was established. This team consisted of Navy and contractor technical experts from Boeing and numerous other original equipment manufacturers. The team provided expertise in areas such as inventory management,

²² Ibid

²³ FIRST Contract, N00383-01-D-001H, 04 May 2001.

contracting, repairs, engineering, and financial management. The NAVICP BCA showed a \$55.4 million cost avoidance to the NWCF (later adjusted to \$52.4 million) and supported entering into a teaming arrangement for the F/A-18E/F aircraft.²⁴

The total reported FIRST program savings was \$126.1 million in cost avoidance for material, operations, and non-supply support elements. Table 1 summarizes the Navy's reported 5-year cost avoidance.²⁵

FIRST Program Savings - Without Verses With FIRST (in millions of \$)			
Description	Without FIRST	With FIRST	Cost Increase/ (Cost Avoidance)
NAVICP BCA			
Material Costs	779.0	771.5	(7.5)
Operations Costs	108.1	63.2	(44.9)
Subtotal NWCF Costs	887.1	834.7	(52.4)
NAVAIR BCA			
Non-Supply Support Element	1,531.2	1,457.5	(73.7)
TOTAL	2,418.3	2,292.2	(126.1)

Table 1. Estimation of Cost Avoidance for FIRST Program Contract

On April 3, 2001, the Acting Assistant Secretary of the Navy (Research, Development and Acquisition) notified congress of the Navy's intent to award Boeing a contract for total logistics support of the F/A-18E/F aircraft.²⁶

5. Actual Cost of FIRST Program as of August 2004

Three years into the execution of the contract the Office of the Inspector General for the Department of Defense published a report that was highly critical of the Navy's original BCA.

The Office of the Inspector General of the Department of Defense (IG DoD) reports that the Navy BCA used to justify the award of the FIRST contract overstated the cost of DoD performance. That condition occurred because the Navy BCA used:

²⁴ Ibid

²⁵FIRST Contract, N00383-01-D-001H, 04 May 2001.

²⁶ Ibid

- Unreliable data to calculate in-house consumable and repairable item prices;
- An outdated matrix to calculate in-house repair costs versus historical data from naval depots;
- Savings associated with NAVICP cost recovery rates for obsolescence and net loss not justified;
- Cost avoidances NAVAIR claimed relating to integrated logistics support elements not fully supported or justified; and
- A nontraditional methodology to calculate the in-house cost of managing consumable items.²⁷

The Navy did attempt to implement PBL, but without a proven methodology to determine organic maintenance support costs the Navy was unable to accurately assess the true cost avoidance. Additionally, at the time the BCA's were being conducted the GAO reported that the Navy lacked an effective data system for collecting and analyzing information relevant to material cost and usage.²⁸ As a result, the business case used to justify the FIRST contract for life-cycle support of the F/A-18E/F peculiar aircraft components overstated the cost of DoD performance.²⁹

The IG DoD was able to use real cost data to calculate the actual costs of NAVICP material costs without FIRST to be \$573.8 million not the NAVICP estimate of \$779.0 million over 5-years. This overestimation of in-house costs has proved troublesome to the Navy. Table 2 summarizes the IG DoD adjustments made to the Navy's reported 5-year cost avoidance.

²⁷ FIRST Contract, N00383-01-D-001H, 04 May 2001.

²⁸ GAO Report No. GAO-02-565, "Navy Needs Plan to Address Rising Prices in Aviation Parts," May 31, 2002.

²⁹ Department of Defense Office of the Inspector General Report No. D-2003-120, "F/A-18 E/F Integrated Readiness Support Teaming Program," August 8, 2003.

IG DoD-Corrected FIRST Program Savings (in millions of \$)			
Description	Without FIRST	With FIRST	Cost Increase/ (Cost Avoidance)
NAVICP BCA			
Material Costs	573.8	783.1	209.3
Operations Costs	119.5	63.2	(56.3)
Subtotal NWCF Costs	693.3	846.3	153.0
NAVAIR BCA			
Non-Supply Support Element	1,531.2	1,521.0	(10.2)
TOTAL	2,224.5	2,367.2	142.8

Table 2. IG DoD-Corrected FIRST Program Savings

The Navy did not agree with either the findings or the recommendations. The Navy believed it used an appropriate methodology to prepare its business case analysis for the FIRST Program and that the business case analysis initially used to justify award of the FIRST contract was fully justified.³⁰

³⁰ Department of Defense Office of the Inspector General Report No. D-2003-120, "F/A-18 E/F Integrated Readiness Support Teaming Program," August 8, 2003.

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III. METHODOLOGY

A. BASELINE

In order to answer our research question “How can program managers accurately compute the value additive (i.e., in terms of dollars and Operational Availability (A_o)) when sub-component reliabilities or logistics support elements change?”, three different scenarios were drafted in an attempt to determine if eliminating and outsourcing maintenance level activities of weapon systems or sub-components of a system affect the overall Total Life Cycle Cost (LCC), Reliability, and A_o . To measure changes in LCC and A_o , spreadsheet and simulation models will be used for comparing several options. The spreadsheet model was used to reflect the financial justification to determine the value of improved reliability. The simulation model was to be used to reflect the contribution of an incremental increase in Reliability to the system’s A_o . However, before any comparison could be made, the first critical step was to determine a baseline. In this project, the current organic procedure for performing maintenance at any level or type will be considered the baseline scenario and which will be specifically annotated for each scenario in Chapter 4. This baseline scenario will be used as the benchmark criteria for which other options will be evaluated against. It is hoped that the analysis provided from this report will better assist Program Managers (PMs) in making sound decisions when options are being proposed.

B. MODELS

Three models were used in this project. Two models using the Microsoft Excel spreadsheet program as a decision support tool to calculate LCC of a weapon system. This spreadsheet was originally designed by Professor Keebom Kang of the Naval Postgraduate School, Monterey, CA. The original model was first used for the “Vertical (Take off and Landing) Tactical Unmanned Air Vehicle” (VTUAV) case study³¹ and was adopted for this project to further study actual UAV systems currently in use by the Department of Defense (DoD).

³¹ MBA VTUAV Case Study by Prof Keebom Kang, Logistics Engineering (GB 4410) Lecture Notes, Naval Postgraduate School, Monterey, CA.

The first spreadsheet is called the “Large LCC” and focuses on the entire Life Cycle Cost structure which encompasses RDT&E, Production, System Components, and Operational Support functions such as Training, Manning, and Maintenance levels. The Large LCC spreadsheet will be used in Scenarios One and Two. The second spreadsheet called the “Small LCC” focuses specifically on the Intermediate (I) Level Maintenance Activities. While these spreadsheets concentrate on LCC and reliability, the third model uses a Simulation software package called “Arena”³² as a decision support tool for PMs to determine A_0 of a weapon system. Both the Small LCC and the Simulation Model will be used for Scenario Three.

For the Large LCC spreadsheet model, data will be required to populate the sections on the User Input User page which consists of: 1) General, 2) Training, 3) Operational, 4) Manning, 5) Maintenance & Equipment, 6) RDT&E & Production, and 7) Component Inputs. This User Input Page is linked to the other individual work pages for Manning, Training, RDT&E, O&M, and Totals. The cells with black lettering are static figures that remain the same throughout each scenario but may be changed if required. The cells with RED lettering are input cells which require data. This data are the dynamic figures that are used to compare the differences in LCC changes if any. The cells with BLUE lettering are the computed figures by the model, such as LCC on the User Input page. Once the Input page is populated, the other pages will automatically be updated with the same figures. Key data requirements for the User Input page include “System Components” and “Sub-Components” that need to be identified as “Critical” or “Non-Critical.” Other key data requirements are the cells in red letters such as the “Unit Cost”, “Mean Time Between Failures” (MTBF), “Life Span” of the system in years, and “Manning Requirements” for each level of maintenance activity. The Small LCC model uses the O&M data to populate the fields and follows the same color logic for each of the cells.

For the simulation model, the key data requirements for the Input page are the section MTBFs of the weapon system. For each section, the spare parts level and the

³² Kelton, David W., Randall P. Sadowski, and David T. Sturrock. Simulation With Arena, 3rd Ed. Boston: McGrawHill, 2003.

“Turn Around Time” (TAT) is also used in the A_0 calculation. Transportation costs for each repair is the last variable that is needed to complete the calculation.

C. DATA GATHERING

To collect data for this project, the majority of the fields in the spreadsheet were adopted from Professor Kang’s original model analyzing a VTUAV. The rest of the data was collected from an Army Program Office³³ and a Navy Program Office³⁴ through telephone calls, electronic mails (e-mail), and note taking.

In order to apply this model to current UAV systems, the Army’s Shadow System was used to identify the system components and sub-components; system operational threshold and objective requirements; system manning levels including maintenance requirements; and operational hours. However, pertinent information such as MTBFs, unit cost, and identification of critical and non-critical items were not available from the Shadow system. Instead, this information was retrieved from a UAV System currently under development for the U.S. Navy from the Naval Air Systems Command (NAVAIR). The data gathered from the Navy UAV are either actuals or estimates. Where the program office was unable to provide actual figures, best estimates were provided by NAVAIR to mirror close to actual figures. These estimates were to be second best to actuals based by the group members. Lastly, both the Army and Navy UAV systems only used the Two Level Maintenance Activities of Operational and Depot (O-D).

D. ASSUMPTIONS

Many assumptions were made for this project to expedite the case study. However, careful consideration was made to ensure assumptions fit close to standards and real life scenarios. The areas where assumed figures were used are annotated in the following:

- Large LCC Model User Input Page
 - o General Inputs Data
 - o Training Inputs Data
 - o Operational Inputs – POL & Flt Hour costs only

³³ Army Shadow UAV System (link or info).

³⁴ Naval Air Systems Command (NAVAIR) Program Office

- Manning Inputs – I Level Only
 - Maintenance & Equipment – Test Equipment Cost, I Level Activation Cost, I Level Operating Cost/Year, Depot Repair Cost, and Transportation & Shipment Cost.
 - RDT&E & Production Input Data
 - I Level and Depot Level Repair costs
 - Component Input Data – Reliability Factors
 - HUMMER MTBF and Unit Cost
 - Power Generator Unit Cost
 - Launcher MTBF and Unit Cost
 - Parachute MTBF and Unit Cost
- Training User Input Page – Required Funding for each level
- RDT&E & Production Input Page
- Spare Parts Critical Items having protection level of 95%
- Spare Parts Non-Critical Items having protection level of 85%

E. LIMITATIONS

1. Limitations of the LCC Models

The LCC calculations are only as good as the input data provided. If actual data can be retrieved for every field, the LCC will be a true calculation. Where data provided are estimated or assumed, the spreadsheet then only provides the best possible LCC (but not the exact LCC). The spreadsheet proves to be valuable for LCC cost computation, but the computations are static in nature and does not account for the interactions between reliability, turn-around time, and A_0 . Specifically for this project, the spreadsheet does not capture the dynamic relationship between reliability and Operational Availability (A_0) which is defined as $(MTBM)/(MTBM+MDT)$. A decline in reliability will increase the frequency of failures. This will result in an increased workload for the repair facility. A bottleneck in the repair cycle may develop as the increased workload congests the facility's operations. This additional workload will further result in an increase in MDT and will adversely affect TAT. The spreadsheet model does not capture

this dynamic relationship, but the simulation model does. Lastly, the spreadsheet also does not calculate Operational Availability.

2. Limitations of the Simulation Model

The Arena Model on the other hand is able to capture the calculation of Operational Availability and the dynamic relationship between MTBM and MDT. The limitation for this model is the same for the spreadsheet. The User Inputs become a limitation as only this data is used strictly by the program to calculate Operational Availability. The current set up of the model allows only for an MTBF input of the three sections of the UAV weapon system under ten different program runs. An assumption had to be made of each sectional MTBF, which includes several subcomponents. If the model was developed to include MTBFs of all the subcomponents of one section, then a more accurate assessment of the section MTBF could be determined. Lastly, the simulation does not take cost into account. Therefore, the spreadsheet model and simulation model complement each other for this project.

F. APPLICATION

Though these models were used specifically on the Army and Navy UAV systems only, these models can be used on any weapon system if the data can be retrieved. Once complete and pertinent information of a desired weapon system is retrieved, the data could be entered into these models in lieu of the sections used for the baseline scenarios for the UAV system. As soon as the data cells are filled, a baseline template model will be produced to use as a benchmark criteria to evaluate against any option available. This tool equips the PM in making better sound judgments if a proposal by a contractor is being offered and ensures that a cost effective and reliable weapon system will be available for the war fighter.

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IV. SCENARIO DISCUSSION AND ANALYSIS

Scenario Quick Reference Guide		
<u>A. Scenario One:</u>	Using Spreadsheet Model to Analyze Life Cycle Cost (LCC)	p. 28
1-a:	Effects of Eliminating Intermediate (I) Level Maintenance	p. 31
1-b:	Outsourcing Spare Parts Inventory and Transportation Management	p. 33
<u>B. Scenario Two:</u>	Using Spreadsheet Model to Analyze I-Level Outsourcing	p. 36
2-a:	Effects of Outsourcing Single Critical Component on LCC	p. 41
2-b:	Effects of Outsourcing Entire Weapon System to LCC	p. 44
<u>C. Scenario Three:</u>	Using Spreadsheet and Simulation Models to Analyze Reliability and Operational Availability (A_o)	p. 47
3-a:	Valuing the Incentive to Improve Subcomponent Reliability	p. 52
3-b:	The Effect Turn Around Time (TAT) Has on Total LCC	p. 53

Table 3. Scenario Quick Reference Guide

In this chapter, the Army's UAV Shadow System, described in detail in Appendix A, will be used in three different scenarios to be analyzed using two spreadsheet models and a simulation model. All three models are available from http://web.nps.navy.mil/~mn4310/MBA_project/ Each scenario also offered two options for analytical comparisons against the baseline scenario. For the first two scenarios, a spreadsheet tool called the "Large LCC" model was used to calculate the life cycle cost from research and development, operational deployment, through the disposal phase of a weapon system. The LCCs from each of the options was compared to the LCC of the baseline scenario to show the effect on cost from these options. While the first two scenarios computed LCCs of the weapons system, the third scenario used a second spreadsheet tool called the "Small LCC" and a simulation model. The Small LCC analyzed the impact on inherent reliability had on Total LCC while the simulation model estimated A_o of a weapon system. Additionally, the simulation model captured the dynamic relationship between reliability and A_o . With the spreadsheet model capturing

LCC and the simulation model analyzing reliability and A_0 , both models were key tools in analyzing the following scenarios.

A. SCENARIO ONE

Scenario 1: During the development phase of a certain weapon system, a proposal to significantly increase the reliability of the weapon system is strongly being considered to reduce the logistical footprint of the system and the total Life Cycle Cost (LCC). In addition to the increase in reliability, a change in traditional maintenance structure requirements is strongly being considered to further reduce the logistical footprint. One of the Unmanned Air Vehicle (UAV) programs is strongly being considered. Assume the current maintenance structure for similar UAV systems is a 5/75/20 split between Operational (O), Intermediate (I), and Depot (D) activities, respectively. In this proposal, I-Level maintenance will be performed either at the O or D level maintenance activities. The argument is that with the absence of the I-Level maintenance activity, manpower, training requirements, and maintenance cost savings will significantly reduce the total life cycle cost of the system. This proposal will evaluate two options (1-a. and 1-b.) with varying degrees of maintenance responsibility for the remaining activities.

Scenario 1-a: An option of 30/70 percent split among the O and D maintenance activities respectively is being proposed. In order to achieve this plan, the reliability criteria for the design phase of the system must be decided in order to ensure the operational level, with the appropriate manning levels, will be capable of performing all additional maintenance. Assuming the reliability criteria was established and the MBTFs are the same as those in the baseline scenario with a threshold-operating requirement of 12 continuous hours of operation on station in a 24-hour period. The objective system will be capable of 18 continuous hours of operation on station in a 24-hour period

(1). Calculate the potential cost savings of O-D level maintenance in regards to the new manning levels, training requirements, and maintenance costs annually if this plan is to be executed.

(2). If I Level was not eliminated, but instead outsourced to a contractor, what should the PM be willing to pay for this service with the same level of reliability?

Scenario 1-b: Another option calls for a 10/90 percent split among the O and D maintenance activities, respectively. In addition to the contractor improving reliability for this system, the contractor also proposes to manage spare parts inventory and transportation. To assist the PM in deciding annual cost for the proposed contract, what should be the allowable maximum annual cost for providing this additional proposed service with the same protection level performed organically?

1. Scenario One Decision Support Tool Description

Before attempting to isolate a component or subcomponent of a weapon system for improving reliability or reducing the logistical footprint to determine its relationship to maintenance and Life Cycle Cost (LCC), we now know that the first critical step is to determine the baseline scenario of the particular system. Once the baseline scenario is determined, each individual cost section of General Information, Training, Operations, Manning, Maintenance & Equipment, RDT&E & Production, and Component information need to be identified in the LCC spreadsheet model as shown in Figure 1 (Large LCC). Now that the individual sections could be isolated in the base scenario, a comparison could be made to another option being recommended in lieu of the process or service currently being performed.

For example, before deciding to eliminate or outsource any particular level of maintenance activity of a weapon system to a contractor, the PM needs to be able to compute at what cost the service should be willing to pay for a certain level of readiness. Without this capability, the PM will be unable to determine an accurate Cost Benefit Analysis. The LCC spreadsheet model used in this project is a decision support tool that would significantly help the PM to make an educated Cost Benefit Analysis before making a decision if eliminating or outsourcing a particular service or maintenance will provide additional value to the program and overall system functionality.

2. Spreadsheet Decision Support Tool Application

a. Traditional Maintenance Level Activities in Regards to Cost

Before deciding to eliminate or outsource a particular maintenance level or activity, another important step is first determine the current costs of running this activity annually. This current cost structure can be retrieved from the baseline scenario data produced in Figure 1 (Large LCC). From this model, each of the three levels of maintenance activity's cost structure can be isolated to determine the annual costs for each based on manning, training, and repair costs. Additionally, the level of reliability is provided based on the annual cost. With this information, a PM can view the current level of reliability being provided and current cost simultaneously. If a contractor proposes to perform any level of maintenance for a targeted cost structure and level of reliability, the PM will be capable to perform an educated comparison using this spreadsheet decision tool support application between the contractor's offer and what is currently being performed.

b. The Effect on LCC by Eliminating I-Level Maintenance Activities

(1) Baseline for LCC Spreadsheet Model: For Scenario One, Figure 1 will be used to reflect data for the base scenario. First, the components of the system need to be identified, and then identified further as critical or non-critical items. The unit costs and Mean Time Between Failures (MTBF) of each component also need to be identified. Manning levels for all three maintenance activities and life span of the entire system are a few more necessary data required to populate the LCC spreadsheet model. We will assume critical items will have a spare parts protection level of 95% and non-critical items as 85%. The MTBFs, unit cost, as well as manning requirements are annotated in Figure 1. After all the data is entered into Figures 1 through 1f, this will reflect the baseline scenario of this particular UAV system with LCC. This figure includes cost from RDT&E, Production, Operational Support, and Disposal requirements throughout the life span of 20 years for this system.

(2) Calculating the Cost of I Level Maintenance Activity to LCC: For the PM to decide if the system should deviate from the traditional three levels of maintenance, it is critical to figure what the system's current MTBF and cost structure is.

Specifically, the PM needs to identify the cost of operating the I Level Maintenance Activity annually. From the annual I Level Cost column of Figure 1c (O&M Workbook Page) in Appendix B, the total cost for I Level Maintenance annually could be determined. This amount is the baseline cost for performing I Level Maintenance and would be the potential cost savings for eliminating this particular level of maintenance. However, since the maintenance levels will be transferred to both O and D Levels, a cost comparison between the two could be done using this spreadsheet model to determine if the proposed cost savings could actually be achieved using the same level of reliability.

In addition to identifying the cost of eliminating I level maintenance activities, Figure 1 could also be used as the baseline cost for outsourcing I level maintenance activities to contractors. For example, with the current system level of reliability, along with the annualized cost to organically perform I level maintenance, the PM can now determine the cost ceiling for outsourcing I level maintenance for the same level of reliability. Any dollar amount higher than this figure would not be cost effective, unless the contractor is able to provide a higher level of reliability.

3. Scenario One Model Analysis

a. Scenario 1-a LCC Spreadsheet Model Analysis

(1) Clearly, designing a system with improved reliability would reduce the logistical footprint and overall LCC. However, how does a PM compare this strategy when one of the maintenance levels is being proposed to be eliminated? From Figure 1 (base scenario), the LCC is determined to be \$336,090,952 for a 20 year life span for this particular UAV system. Manning cost is \$605,000 annually while training cost is \$345,000 annually for combined basic and intermediate levels of required training. O, I & D levels of maintenance totals equal \$298,253 for maintenance costs annually which out of this \$203,354 is I level maintenance alone. Spare cost runs approximately \$364,095 annually. Comparing Figure 1 with Figure 1.1 (1-a. scenario) in Appendix B, the new LCC is only \$311,459,139 for the 20 year life span with I Level Maintenance eliminated. Furthermore, the \$605,000 annual cost for manning and the \$126,000 annual cost for training are eliminated. O & D level maintenance cost annually now increases to \$343,443 for two levels of maintenance and spare cost also increases to \$374,595 annually. With an overall Total LCC savings of \$24,631,813 for this particular UAV

system, the PM can make a sound decision that partaking of the proposed maintenance strategy will provide cost savings to the program while maintaining the same level of subcomponent reliability.

(2) In addition to the cost savings of eliminating I level maintenance, the PM also has the capability of determining if outsourcing I level maintenance would be a good option. With this spreadsheet model, the annual savings could be calculated to determine at what cost the annual I level maintenance should be outsourced. For the cost of operating I level maintenance activities annually, manning cost is at \$605,000; training cost is at \$345,000; while repairs cost is at \$203,354. In total, I level maintenance cost is \$1,153,354 annually. This annual cost over the 20 year life cycle of the UAV system accounts for \$35,718,454. If a contractor proposes to perform the I level maintenance for the entire 20 years of the UAV system, the PM is now better informed that the contract should be less than \$35,718,454. If a contractor proposes a dollar more for the same level of readiness, the PM can smartly reject the offer, or be better prepared to negotiate for improved level of reliability.

b. Scenario 1-a Conclusion

From the spreadsheet model analysis, it is safe to assume that deviating from the traditional three level maintenance activities of O-I-D to two levels of O-D provides the program office significant cost savings without reductions in reliability to the overall system functionality for this particular UAV system. It is also important to note that the MTBFs of each of the subcomponents used in the baseline scenario were the same for this scenario. Hence, it is also safe to assume to expect more cost savings in the system's LCC if the MTBFs were improved for all or some of the system's subcomponents in this scenario. The only area in which cost did not decrease was in the annual spare cost, repair cost, and transportation cost calculations. However, to further improve cost savings, the PM is now able to focus further in alternative options in performing spare parts inventory and transportation management to further cut down costs while keeping the same level of reliability for the entire system. Whether the PM has a choice of eliminating or outsourcing any level of maintenance activities, this spreadsheet model may prove to be a very useful tool when it comes to determining the effects on LCC of any weapon system. For example, if the contractor is able to perform

the I Level Maintenance Activity for \$1,153,354 annually, we should expect improved reliability in this service. If reliability of the system would not change from outsourcing, we should expect to budget less than \$1,153,354 annually for this service and nothing more.

c. Scenario 1-b LCC Spreadsheet Model Analysis

For scenario 1-b., three scenarios will be compared for spare parts and transportation costs on an annual basis. The first will be the baseline scenario using data from Figure 1. The second will be from scenario 1-a. using data from Figure 1.1 (30/70 O-D split) in Appendix B. The third will use data from Figure 1.2 (Appendix B) which portrays the data for this particular scenario.

The baseline scenario's spare parts cost is \$364,095 and transportation cost is \$30,600 annually, to equal \$394,695. For scenario 1-a., spare parts cost is \$374,595 and transportation is \$30,600 annually, to equal \$405,195. For this particular scenario, spare parts cost \$416,997 and transportation cost is at a steady \$30,600 annually, to equal \$447,597. There is an obvious upward trend from the baseline scenario to 1-b. The difference between the baseline and 1-a is -\$10,500. The difference between the baseline and 1-b is -\$52,902. The difference between scenarios 1-a and 1-b is -\$42,402. If a contractor proposes to manage spare parts inventory and transportation with the O, I, & D structure still in place, then the PM utilizing this model would know to spend less than \$394,695 annually. Under the O-D maintenance structure (30/70 split), the PM would know to spend less than \$405,195 annually. Lastly, the PM would know to spend less than \$447,597 annually to contract out the management of spare parts inventory and transportation under the O-D maintenance structure with a 10/90 split. For each of the figures provided, the PM may accept a higher cost annually only if the level of reliability could be improved significantly.

d. Scenario 1-b Conclusion

As previously discussed, changing from three levels of maintenance to O-D has potential cost savings, however, spare parts cost increases. Shifting to the 10/90 split in O-D further increases the annual cost in spare parts management. In making a decision to outsource spare parts management and transportation, the PM may provide

additional incentives for the contractor to improve spare parts inventory. For example, if spare parts inventory costs could be decreased significantly by the contractor then the savings could be split between the two as long as reliability and protection levels remain the same. Additionally, cost savings incentives for improving transportation costs and Turn-Around-Time (TAT) (which will be discussed in the next scenario) could also be another option. Overall, the take-away from this scenario is that this spreadsheet model is a very helpful tool to isolate potential cost driving areas such as spare parts inventory and transportation. Once this area is identified, the PM can request for options to further decrease cost while maintaining the same level of reliability.

Microsoft Excel - Figure 1 (Scenario Baseline) [Shared]																										
File Edit View Insert Format Tools Data Window Help																										
Type a question for help																										
K37																										
VTUAV Life Cycle Cost (LCC) Analysis: User Inputs													VTUAV Life Cycle Cost (LCC) Analysis: MTBF Inputs													
General Inputs													Manning Inputs													
Capital Discount Rate 10%													O-Level H-Level D-Level													
Inflation Rate 4%													Others 2 1 1													
Manpower Attrition Rate 20%													CPOs 1 1 2													
Peace Time Loss Risk (Min/Max/Default) 2% 7% 5%													E-1 to E-6 19 5 8													
Contingency Loss Risk (Min/Max/Default) 15% 30% 15%																										
Contingency Chance 15%													Maintenance/Equipment Inputs													
Number of Reconnaissance, Strike Base and Targeting Squadrons (RSTA) 1																										
Number of Systems Squadron 1													Number of AVs per System 4													
Office Salary \$ 140,000													Number of GCS per System 2													
CPO Salary \$ 115,000													Number of Items in each GCS 2													
E-1 to E-6 Salary \$ 10,000													Number of GDT per System 2													
Life Years of Program 20													Number of RVT per System 4													
AV Unit Cost \$ 1,000,000													AV Unit Cost \$ 1,000,000													
Ground Control Equip Cost \$ 8,500,000													Ground Control Equip Cost \$ 8,500,000													
Test Equipment (I-Level) Cost \$ 50,000													Test Equipment (I-Level) Cost \$ 50,000													
Critical Protection Level 0.95													Critical Protection Level 0.95													
Non-Critical Protection Level 0.85													Non-Critical Protection Level 0.85													
TAT (days) ~ I-Level 20													TAT (days) ~ I-Level 20													
TAT (days) ~ D-Level 40													TAT (days) ~ D-Level 40													
Number of I-Levels 1													Number of I-Levels 1													
I-Levels/Squadron 1													I-Levels/Squadron 1													
Failures Repaired At O-Level 5%													Failures Repaired At O-Level 5%													
Failures Repaired At I-Level 75%													Failures Repaired At I-Level 75%													
Failures Repaired At D-Level 20%													Failures Repaired At D-Level 20%													
Spare Level Factor 0.5167													Spare Level Factor 0.5167													
Annual Inventory Rate 21%													Annual Inventory Rate 21%													
H-Level Repair Cost \$ 3,000 per repair													H-Level Repair Cost \$ 3,000 per repair													
O-Level Repair Cost \$ 1,000 per repair													O-Level Repair Cost \$ 1,000 per repair													
POL Cost/Flight Hour \$ 60.00													POL Cost/Flight Hour \$ 60.00													
Month Year													Month Year													
Ground Equip Hours 240 2880													Ground Equip Hours 240 2880													
AV Flying Hours/Vehicle 125 1500													AV Flying Hours/Vehicle 125 1500													
Air/Land & Launch/Rec Hours 48 576													Air/Land & Launch/Rec Hours 48 576													
Production Line Open Costs \$ 12,000,000													Production Line Open Costs \$ 12,000,000													
RDTE Year 1 \$ 15,000,000													RDTE Year 1 \$ 15,000,000													
RDTE Year 2 \$ 20,000,000													RDTE Year 2 \$ 20,000,000													
RDTE Year 3 \$ 50,000,000													RDTE Year 3 \$ 50,000,000													
RDTE Year 4 \$ 50,000,000													RDTE Year 4 \$ 50,000,000													
Number of Years Line Open 25													Number of Years Line Open 25													
First Year of Production 4													First Year of Production 4													
Disposal Cost/system \$ 0													Disposal Cost/system \$ 0													
LIFE CYCLE COSTS													LIFE CYCLE COSTS													
\$ 336,090,952													\$ 336,090,952													
Red Numbers = Inputs													Red Numbers = Inputs													
Blue Numbers = Computed													Blue Numbers = Computed													
User Inputs / Manning / Training / O&M / RDTE / Totals / graph / Poisson /																										

Figure 1. Baseline Scenario (User Inputs Page)

Scenario Two will continue using the “Large LCC” model. However, instead of eliminating I-Level completely the model will be used to evaluate how outsourcing I-Level, for an individual component or for the entire UAV system, affects LCC. Multiple variables will be changed to show the complex relationship between each of them. This scenario will show the difficulties that a PM has in determining if a PBL initiative should be entered and what the incentive is worth if achieved by the OEM.

B. SCENARIO TWO

Scenario 2: A PM is considering a PBL contract to outsource the I-Level maintenance activity to the Original Equipment Manager (OEM) of a UAV system. It must be decided if the outsourcing of the I-Level maintenance activity will be for the entire weapon system or only a critical subcomponent of the weapon system. An analysis on reliability, TAT (i.e., Sum of test and check time, repair time and transportation time), training costs, labor costs (i.e., manpower reduction and contract labor vs. organic labor), I-Level facility costs and the impact on LCC will be used to determine which option will be the better investment. A system consists of four UAV’s and maintains an operational capacity of 125 hours per weapon system a month.

Scenario 2-a. A contract proposes that the I-level maintenance activity be outsourced for a single critical component. The PM has determined that the UAV Engine, with a MTBF of 1,187 hours, is the most critical component. Currently, when a subsystem fails, it is sent to the service’s organic I-Level for repair. The TAT for organic I-Level repair is 20 days. Under the proposed contract the I-Level would not repair the engine but would maintain an Engine Test Facility for Test and Check and minor calibration adjustments. If the engine is found to be in need of repair then it would be shipped to the OEM for repair and returned to inventory once the repair was completed. The PM has estimated that the elimination of the repair function at the organic I-Level will reduce junior E-1 to E-6 manpower from five technicians to two. Additionally, the basic training time for the remaining E-1 to E-6 technicians will be reduced from 20 weeks to ten weeks.

The OEM proposes to improve MTBF to 1,500 hours through system redesign. Due to the increased time for the system to be tested at the organic I-Level and shipped to and from the I-Level rework facility at the OEM the TAT for repair and transportation will increase to 30 days. The warehousing of inventory spares and delivery to the end user will remain with the Service. The OEM contractor will be required to maintain the same spare part protection level of 95 percent on station. The PM understands that by increasing the TAT, and requiring the OEM contractor to maintain a 95 percent protection level of spares, that there will be an possible increase in costs associated with the need to carry additional spares on station.

(1) Will the reduction in training and personnel costs be greater than the increase in spare part inventory costs?

(2) If so then, this savings amount will be the maximum amount that the PM would be willing to pay for outsourcing the engine to the OEM.

(3) If the OEM demonstrates a 313 hour increase in MTBF of the engine what will the monetary incentive be for that increase?

Scenario 2-b. Under this option, the PM will outsource the I-Level maintenance activity of an entire weapon system. Currently, when a subsystem fails, it is sent to the service's organic I-Level for repair. The PM has determined that the service's organic I-Level has an operating cost of \$6 million per year, manning is at seven personnel and the cost for each repair is \$3,000. Additionally, the TAT for organic I-Level repair is 20 days.

Under the proposed contract the OEM proposes to occupy the service's I-Level spaces on the military installation which will be used as their maintenance site. All maintenance will be performed by OEM personnel using the existing test equipment. The OEM proposes to reduce TAT at the I-Level to ten days, reduce manning at the I-Level by one person and reduce working hours at the facility by 50 percent. These reductions are estimated to lower I-Level facility operating costs by 20 percent annually. However, the cost for each repair will double from \$3,000 to \$6,000 due to the increase

in skilled labor and the annual cost for one OEM maintenance person will equal that of an officer (i.e., \$120,000 per year).

(1) Will the reduction in TAT, facility operating cost, organic manning and training be greater than the increase in repair costs and manning salary?

(2) If so then, this savings will be a monetary incentive for the OEM to maintain a TAT of 10 days.

1. Scenario Two Decision Support Tool Analysis

Before a PM can make a decision to outsource the entire I-Level maintenance activity to the OEM or outsource just a critical component the baseline scenario must be determined. Once the baseline scenario is determined, each individual cost section of RDT&E, Procurement, Operational Support, and Disposal can be identified in the LCC spreadsheet model as shown in Figure 1 (Large LCC). These individual cost sections can be isolated in the base scenario and a comparison can be made between the two options to determine which one will provide the greatest LCC savings over the life of the program. The LCC spreadsheet model used in this project is a decision support tool that would significantly help the PM to make an educated Cost Benefit Analysis before making a decision if outsourcing the entire I-Level maintenance or just a critical component will provide additional value to the program and overall system functionality.

2. Spreadsheet Decision Support Tool Application

a. Traditional Maintenance Level Activities in Regards to Cost

As described in scenario ONE, a determination of current costs to run the I-Level maintenance activity annually is necessary. These costs can be retrieved from the baseline scenario data produced in Figure 1 (Large LCC). From this model, each of the three levels of maintenance activity's cost structure can be isolated to determine the annual costs for each based on manning, training, and repair costs. Additionally, the level of reliability is provided based on the annual cost. With this information, a PM can view the current level of reliability being provided and current cost simultaneously. If a contractor proposes to perform any level of maintenance for a targeted cost structure and level of reliability, the PM will be capable to perform an educated comparison using this

spreadsheet decision tool support application between the contractor's offer and what is currently being performed.

b. The Affect on LCC by Outsourcing I Level Maintenance Activity for a Single Critical Component

(1) Baseline for LCC Spreadsheet Model: Under Scenario 2-a, the PM must decide the value added for each option available. Outsourcing organic I-Level maintenance for a single critical component (i.e., the Engine of the UAV) to the OEM will result in longer TAT due the increased distance the critical component must travel to and from the repair site. Additionally, since the requirement to repair the Engine has been removed from the I-Level it has been determined that the manning level for junior maintenance personnel, E-1 to E-6, will be reduced from five to two and the training time will be reduced from 20 weeks to ten. Isolating these variables the PM is able to measure the change in LCC if the I-Level maintenance activity is outsourced for the Engine. Figure 1 and all populated data are the baseline for this scenario. Figures 1 through 1f reflect the baseline scenario of this particular UAV system. This figure includes cost from RDT&E, Production, Operational Support, and Disposal requirements throughout the life span of 20 years for this system. All data are assumptions for analytical analysis only.

(2) Calculating the Cost of I-Level Maintenance for a Single Critical Component to LCC: For the PM to decide if the UAV engine should deviate from the traditional organic I-Level maintenance, it is critical that the current MTBF and cost structure be calculated. Specifically, the PM needs to identify the cost of training/week (i.e., Basic and Advanced), labor costs (i.e., I-Level repair cost per repair), Officer and Enlisted salaries, and the impact on LCC. From the annual I-Level costs column of Figure 1c (O&M Workbook Page) in Appendix B, the total cost for organic I-Level maintenance could be determined. In the same column the annual cost of performing organic I-Level repair on each individual item is also identified. This amount is the baseline cost for performing traditional organic maintenance on the component. Once the baseline is determined then the changes to manning (i.e., reduction in training weeks for I-Level Basic Maintenance. Training and number of I-level personnel needed), and MTBF for the Engine could be made to Figure 1 (User Inputs Workbook Page).

Additionally, the TAT for the Engine will be adjusted using the TAT (days) I-Level outsource block L19 of Figure 1.

To allow the model to change the TAT for a single component (i.e., the engine) the user must modify the equation in cell G22 of the O&M workbook page from $=AVHours * SpareLevelFactor$ to $=AVHours * SpareLevelFactorOut$. This change can be made to any of the corresponding cells (i.e., G23 will change the TAT for the propeller) to change the TAT for a single component. When cell G22 is changed only the TAT for the engine will be changed all other I-Level TAT's will reflect the number in cell H22, TAT (days) I-Level, of Figure 1. The PM can now determine the cost ceiling for outsourcing I-level maintenance for a critical component. Any dollar amount higher than this figure would not be cost effective, unless the contractor is able to provide a higher level of reliability.

c. The Affect on LCC by Outsourcing I-Level Maintenance Activity

(1) Baseline for LCC Spreadsheet Model: Figure 1 and all assumed data that was used in Scenario One will be used for the base scenario in Scenario 2b.

(2) Calculating the Cost of I-Level Maintenance Activity to LCC: For the PM to decide if the system should deviate from the traditional organic I-Level maintenance, it is critical to calculate what the system's current MTBF is for each individual component and the cost structure at the I-Level. Specifically, the PM needs to identify the cost of training/week (i.e., Basic and Advanced), labor costs (i.e., I-Level repair cost per repair), Officer and Enlisted salaries, I-Level operating cost per year and the impact on LCC.

Once the PM identifies the costs then they can be used to populate the model. From the annual I-Level costs column of Figure 1c (O&M Workbook Page) in Appendix B, the total cost for organic I-Level maintenance could be determined. This amount is the baseline cost for performing traditional organic maintenance on the component. Additionally, the annual cost for manning and training, as seen in Figure 1a (Manning Workbook Page) and 1b (Training Workbook Page) in Appendix B, could be determined. These costs along with annual I-Level operational costs are the baseline for the cost of organic I-Level maintenance.

Once the baseline is determined then the changes to manning (i.e., reduction of all I-Level Basic and Advanced Maintenance Training and all I-Level personnel), TAT, I-Level repair cost, and reduction in I-Level operating costs/yr can be made to Figure 1 (User Inputs Workbook Page). The PM can now determine the cost ceiling for outsourcing I level maintenance for the same level of reliability. Any dollar amount higher than this figure would not be cost effective, unless the contractor is able to provide a higher level of reliability.

3. Scenario Two Model Analysis

a. Scenario 2-a LCC Spreadsheet Model Analysis

Scenario 2-a will analyze outsourcing the I-Level maintenance of a single component with the incentive to improve reliability through system redesign. Primarily, Scenario 2-a focuses on this issue on a macro scale with multiple variables changing (i.e., MTBF, TAT, manning levels, and training time) each independently effecting LCC in a positive or negative way. Additionally, the scenario addresses the highly controversial issue of removing all I-Level testing capabilities for the service. Scenario 2-a does not remove the I-Level function entirely; it allows the service to continue to test the component to ensure the item is defective prior to being shipped to the OEM for I-Level repair. This capability is thought by some to be a necessary check to ensure the component is not shipped to the OEM with no defects a term known in the Navy as A-799.

The LCC Spreadsheet Model is a flexible model that allows the PM to change multiple variables to see the effect on LCC. In Scenario 2-a the baseline is the same as Scenario 1, Figure 1. All LCC cost figures have been adjusted for inflation and NPV and all annual figures are in current year dollars. From Figure 1 (Base Scenario) the LCC is determined to be \$336,090,952 for a 20 year life span for this particular UAV system. Figure 1a in Appendix B shows total manning salary cost to be \$3,260,000 annually beginning in FY 2005 and a total LCC cost to be \$26,746,466. This amount includes manning salaries at the O, I & D levels of maintenance. However, this scenario is only concerned with the manning salaries of the enlisted personnel at the I-Level which is \$350,000 annually.

Figure 1b in Appendix B shows training which will begin in FY2004, one year prior to the UAV system being fielded at an annual cost of \$871,000. Since the initial training of personnel is completed prior to a system being fielded, the initial cost of \$871,000 will be for FY2004 only. Once initial training is completed there will only be a need to train replacement personnel for the maintainers that leave service or transfer to other systems. Our model assumes that there will be a 20 percent attrition rate for all personnel. Beginning in FY 2005 the total training cost for O, I, &D Level personnel is shown to be \$345,000 annually. However, this scenario is only concerned with the I-Level basic training costs for the E-1 to E-6, junior enlisted, maintenance personnel which is \$160,000 for FY2004 and \$32,000 annually thereafter. Additionally, the total training LCC is shown to be \$3,526,507.

Figure 1c in Appendix B shows the O&M costs for the entire UAV system. The total O&M LCC cost is \$56,004,907. However, in this analysis the focus will be on the engine which the PM has considered to be the most critical component to outsource to the OEM. With an estimated 1,500 flight hours per UAV per year and an engine MTBF of 1,187 hours the number of engine failures per year per UAV system is eight. The PM has determined that the organic I-Level TAT is 20 days for the engine. Additionally, the PM requires that all critical components be stocked at a 95 percent confidence level. Given this, the number of spares need to meet this requirement is two. The price for each Engine is \$75,000. Therefore, the initial cost for spares is \$428,271, the annual I-Level maintenance cost per system for the engine is \$11,373, and the annual spare part carrying cost is \$179,874.

To answer the first two questions of the scenario, three of the four variables (i.e., TAT to 30 days, reduction in E1 to E-6 manpower from five to two, and reducing the training time from 20 weeks to ten) must be changed in the Users Input page of the baseline model. After the change, Figure 2.1 (Appendix B) displays the new LCC to be 334,134,474. This is a significant change from the original LCC of \$336,090,952. The savings equates to a LCC reduction of \$1,956,478 over the 20 year life span of this particular UAV system. Since the reduction in training and personnel costs were greater than the increase in spare part inventory costs the outsourcing of the I-Level can be

justified by the PM. Additionally, the PM now knows the savings over the life-cycle of the UAV system and is able to use this amount as the baseline for the contractual agreement with the OEM. The PM should not pay more than \$1,956,478 over the 20 year life span of this particular UAV system unless the MTBF of the engine is improved and demonstrated.

Further comparisons can be made in each of the Workbook pages to understand how the cost savings were calculated. In the baseline scenario, the manning salary of the enlisted personnel at the I-Level was \$350,000 annually. Figure 2.1a in Appendix B shows that by reducing the I-Level enlisted manning the annual cost is \$140,000 a savings of \$210,000 per year. The new LCC for manning is \$25,023,535 down from the baseline amount of \$26,746,466. This savings equates to a total LCC cost savings of \$1,722,931.

The reduction in personnel and training time for the enlisted maintainers at the basic I-Level is shown in Figure 2.1b in Appendix B. The new basic training costs of the I-Level E-1 to E-6 maintenance personnel in FY 2004 went from \$160,000 to \$32,000 and in the following years training cost was cut from \$32,000 to \$16,000 annually. The total LCC for training went from \$3,526,507 to \$3,292,960. This is a savings of \$233,547 over the 20 year life of the UAV system.

The outsourcing of the I-Level increased the TAT from 20 days to 30 days. Figure 2.1.c (Appendix B) displays the O&M Workbook page. It can be seen that there is no change in the number of spares needed to meet the 95 percent fill rate. Therefore, there is no change in LCC as a result of a ten day increase in TAT.

To answer question three of this scenario, the final variable (i.e., increasing MTBF of the engine to 1,500) needs to be inserted into the model. After the change, Figure 2.2 in Appendix B reveals that the LCC went from \$334,134,474 to \$334,099,353. This is a cost saving of \$35,121 over the 20 year life of the UAV system. Therefore, it can be determined that the value of increasing the MTBF of the Engine by 313 hours is worth \$35,121 and that the OEM should not be given an incentive any larger than this amount to increase the MTBF to 1,500 hours.

A closer analysis of the changes reveals that O&M costs were affected in the following ways. Figure 2.2.c in Appendix B shows that when the MTBF was increased to 1,500 hours the number of failures per year was cut in half from eight to four. This reduced the annual cost for O, I, &D Level maintenance from \$298,253 to \$294,772 a savings of \$3,481 annually. The remaining annual savings can be seen in the reduction of transportation costs. Transportation cost goes from \$30,600 to \$29,800. This equates to a combined savings of \$4,281 annually.

b. Scenario 2-a Conclusion

Using the LCC model to study a highly complex issue of changing multiple variables in the logistics and maintenance cycle of one critical component reveals a multitude of useful information for the PM. The PM is able to understand the interrelationships between how the outsourcing of a maintenance level will affect TAT, manning, training and O&M costs over the entire life-cycle of a system. Additionally, the PM can determine what the proposed outsourcing is worth in cost savings and what the incentive is worth if the improvement in MTBF is demonstrated by the OEM. This useful tool will arm the PM with critical information that he or she could use to make the right choice at the right price.

c. Scenario 2-b LCC Spreadsheet Model Analysis

Scenario 2-b addresses a complex issue of determining the value of a proposed outsourcing of an entire maintenance echelon. This scenario is unique in the fact that the OEM maintenance personnel will occupy the existing I-Level maintenance facility. The OEM has determined that they would be able to reduce manning from seven to six and reduce the working hours at the facility by 50 percent. These reductions are estimated, by the OEM, to lower I-Level operating cost by 20 percent annually. However, the cost per repair will double and the annual salary amount will increase because of the increase in skilled labor (i.e., OEM maintenance person will equal that of an officer, \$120,000 per year). The PM must be able to determine the baseline amount that he or she would be willing to pay for the outsourcing and determine the value of the reduction in I-Level facility operating costs over the life-cycle of the program. This value will be the maximum that the incentive will be worth if demonstrated by the OEM.

The baseline model will use the same baseline as scenario 2-a. Figure 1 shows the LCC for the UAV system, using all three levels of organic maintenance, to be \$336,090,952. All manning, training and O&M workbook pages are identical to scenario 2a.

The following variables have been changed in the user input page of the baseline model to simulate scenario 2-b.

- Reduced manning from seven to six and moved all six into the Officer Manning block to simulate the \$120,000 a year salary.
- Set all training weeks for I-Level to zero.
- Reduced I-Level TAT from 20 days to ten days.
- Increased cost per repair at the I-Level from \$3,000 to \$6,000.

Figure 2.3 in Appendix B reveals that after the changes were made that the LCC for the UAV would increase from \$336,090,952 to \$336,972,573. This increase of \$881,621 clearly shows that the reduction in TAT, facility operating cost, organic manning and training would not be greater than the increase in repair costs and manning salary. This justifies that the proposal should not be accepted unless the OEM was willing to reduce the cost per repair or reduce the manning costs.

If however, the PM would have entered all the variables at the same time including the estimated 20 percent reduction in I-Level facility operating cost the picture would have been much different. Figure 2.4 in Appendix B shows scenario 2-b with all the proposed changes. The LCC indicates that the potential savings could go from \$336,090,952 to \$327,127,254 a savings of \$8,963,698. Clearly, the picture would have given the impression that entering into this venture had the enormous possibility to save the PM a great deal of money over the life-cycle of the program. However, what the PM would not have seen is what the program would cost if the savings, which were promised by the OEM, were never realized.

d. Scenario 2-b Conclusion

Using this LCC model to evaluate a complex scenario of changing from an organic maintenance structure to an outsourced one with multiple changing variables can provide the PM with valuable information on what each change is worth. Understanding how each variable changes LCC and seeing the weight each incremental change is worth is priceless to a PM when they are faced with complicated decisions like this one. Once the PM realized that the original proposal would cost the program more money, if the estimated savings were not realized, then he or she could adjust either, the number of maintenance personnel, the annual amount of manning salary, or the cost for each I-Level repair until the breakeven point was indicated. Once the breakeven point was known, then the PM could counter offer with a different proposal and offer the estimated percentage of facility operating cost reduction as an incentive which would be paid if the OEM could actually demonstrate these savings.

The Large LCC model is comprised of six worksheets that represent the major cost drivers of the total ownership cost of the weapon system. The model shows in intricate detail how each worksheet is linked and contributes to the total Life Cycle Cost by changing the input parameters in the worksheets. The static nature of this model is unable to analyze the relationship between reliability and Operational Availability. For example, any decline in reliability will result in an increased occurrence of failures. This will multiply the workload at the repair facility. As a consequence, a greater workload at the repair facility runs the risk of congestion and a bottleneck in repair operations may occur. This will negatively affect MDT and TAT will increase as a result. In an attempt to compensate for this limitation, the Small LCC model and a simulation based model are used to reflect this dynamic relationship. To depict this relationship, the Small LCC analyzes the impact of component reliability changes on the Total Life Cycle cost while the simulation based model estimates Operational Availability. The Small LCC model will provide resource managers with information about the costs associated with improvements in reliability, while the simulation model will provide information to the warfighter about the contribution of increased reliability to Operational Availability. Both models will be used in scenario Three analysis.

Scenario Three will evaluate the impact that potential incentives may have if incorporated into a weapon system contract. The scenario will use the Small LCC model and simulation model to evaluate the financial impact on Life Cycle Cost and contribution to Operational Availability of an incentivized contract to redesign a subcomponent of a weapon system. This scenario will also use the Small LCC model to analyze the effects TAT has on the logistical footprint required to support a weapon system.

C. SCENARIO THREE

Scenario 3: A Program Manager (PM) is seeking to incentivize a contract that will encourage contractors to improve reliability and reduce total ownership costs for specified subcomponents of a weapon system. Within this contract, the PM is considering the option to outsource the I-Level maintenance activity for a particular subsystem. Potential contractors have expressed interest in redesigning the subcomponent to achieve a greater MTBF, and reduce the turn around time (TAT). The spare parts inventory will be managed by the service. If the PM decides to outsource maintenance, labor costs will increase. After examining the current cost schedule of the I-Level maintenance activity, the PM must determine if outsourcing is the best course of action for the program. Quantifying the value of a monetary incentive for a gain in reliability is needed to assist the PM in making the right financial investment decision. A system consists of four UAVs and maintains an operational capacity of 125 hours per weapon system a month

Scenario 3-a. Currently, the portable GCS has an MTBF of 200 hours, with a unit cost of \$100,000. Assume that the I-Level repair time for the portable GCS is 20 days and labor costs are \$100/hr. The outsourcing of this maintenance activity for the subunit will increase the labor costs to \$500/hr. What information will be needed and how would the PM justify an incentive to improve the MTBF to 500 hours?

Scenario 3-b. The contractor does not redesign the portable GCS, i.e. the MTBF has no change, but proposes to decrease the TAT. What value would this decrease in TAT have for the program?

1. Decision Support Tool Description

Attempting to isolate one subcomponent of a weapon system unveils how several other cost variables are interconnected and contribute to the total ownership costs. The LCC is a complex equation and altering any one variable will change the entire equation. A PM seeking to determine the most cost effective investment for a program requires an analysis that ensures the contribution to the LCC is identified, while being able to ascertain the effects of changing one variable. A financial spreadsheet model that is capable of providing this information can be utilized as a decision support tool for the PM to make sound investment decisions, as depicted in Figure 3 in Appendix B. This model will compute spare parts requirements, transportation, inventory, and repair costs over the life cycle of the weapon system. A key limitation to the Small LCC model is the static nature that is unable to compute operational availability and capture the dynamic relationship between the mean time between maintenance (MTBM) and maintenance downtime (MDT). This model focuses only on reliability and maintainability of the weapon system. Yet the spreadsheet model is valuable to the PM for cost computation.

However, the limitations of the spreadsheet model can be alleviated by the use of a simulation model, as depicted in Figure 3.1 in Appendix B. This model can evaluate and graphically depict the contribution to the operational availability of any investment in the improvement of reliability for a weapon system. To illustrate this, a simulation model mimics the dynamic relationship of MTBM and MDT within the Operational Availability equation: $A_o = \text{MTBM} / (\text{MTBM} + \text{MDT})$. Having these two decision support tools will better equip the PM to manage a program that is cost effective and reliable for the war fighter.

2. Spreadsheet Decision Support Tool Application

a. PM and Contracts

The PM seeking to reduce total ownership costs and increase the reliability of a particular subunit of a weapon system must take a creative and realistic approach in contract details as costs usually increase with an increase in reliability. Another challenge for the PM is a DoD experiencing budget atrophy. The PM has a difficult mission to get the most bang for each tax payer dollar and is further burdened

with the need to accurately value the contributions of a potential contractor in accomplishing this mission. Incentivizing a contract will allow the PM to specify the requirements in the contract and the return to the contractor for achieving the desired results. The benefit of incentivizing a contract will also encourage potential contractors to be innovative and find cost saving methods in their attempts at creating a winning bid. The contractor and the government will enjoy a positive return on investment as a result of implementing incentives in a contract. The financial decision support tool will allow for the PM to measure the worth of each incentive that may be placed in the contract. The PM will also be able to quantify the proposals within a contract to determine the value added to the program.

b. The Effect on LCC by Outsourcing Organic I-Level Maintenance

(1) Baseline for LCC Spreadsheet Model: Scenario Three, Figure 3 in Appendix B, the PM must decide the value added for each option available. Outsourcing organic maintenance to a contractor normally comes with an increase in labor costs. The Intermediate Level maintenance requires more skilled labor, which will further increase labor costs. Isolating this one variable, labor costs, the PM is able to measure the change in LCC if the I-Level maintenance activity is outsourced for a particular subunit. Performing this calculation will provide the PM a baseline metric to determine the value addition for a proposed increase in either reliability or turn-around-time (TAT) by the contractor. Assume the annual cost of capital for the PM's calculations is at 10%. The current organic maintenance cost for the portable GCS is \$115,200, and the total repair cost for the system is \$1,704,960. The current cost per weapon system per year is calculated to be \$3,398,184. This annual cost adjusted for the twenty year life cycle comes to \$22,861,283.

(2) Calculating Contract Labor Cost to LCC: Data collected by the PM determines the aggregate average organic I-Level maintenance labor rate to be \$100/hr. The outsourcing of this maintenance activity will increase labor costs to \$500/hr. Using the decision support tool, the PM is able to quantify the immediate financial impact the increased labor costs will have on the total repair costs for the portable GCS, the total cost per system per year, and the LCC for the system. The increase in labor costs raises the total repair cost of the portable GCS to \$576,000, an

increase of \$460,800. This increase raises the total annual cost per system per year to \$3,858,984. Outsourcing the maintenance activity will result in an addition of \$3,100,032 to the LCC, bringing the new total LCC to \$25,961,315.

Recall the base scenario's LCC was \$22,861,283. The \$3,100,032 total increase in LCC costs from outsourcing maintenance alone must be justifiable in terms of value added to the program. Committing capital resources to outsource maintenance will require an accurate measure of value added to the program. Inherent to each weapon system is the demand for reliability. Essential to reliability is the MTBF of a weapon system and its subcomponents. Assuming the TAT remains at 20 days, the PM is aware that outsourcing the maintenance activity alone raises the repair cost for the portable GCS by \$460,800 and a total increase of \$3,100,032 to LCC. This overall increase in LCC is an area to be targeted for incorporating incentives into the contract that will bring value to the program in terms of improved reliability.

c. Contractor Incentive to Improve MTBF Through Redesign

Seeking to improve the reliability of the portable GCS, the PM has the ability to quantify the worth of any incentive that may be incorporated into the contract that will increase the reliability. Assuming the current MTBF to be 200 hours, the PM discovers that at 215 hours, the number of spare parts reduces by one, requiring eight spares to be in inventory. Assume the annualized spare cost is at 21% is \$168,000, equivalent to a reduction to 18 days of TAT. What differs is the number of failures per system per year. The portable GCS is a subunit of the ground control station (GCS). The GCS has a monthly operational requirement of 240 hours. To calculate the number of failures, the formula $\text{GCS monthly hours} \times (12 \text{ months}/\text{MTBF})$ is used. The 200 hours MTBF for the portable GCS results in an average of 14.4 failures per UAV per year, and 115.2 failures per weapon system. Increasing the MTBF to 215 hours, 13.4 failures will occur per system per year, and 107.2 failures per weapon system per year. If a contract were to increase the MTBF to this amount, the value of those fifteen additional MTBF hours result in one less spare part required to be managed in inventory, one less failure, and \$40,186 in savings for total repair costs. The savings to total cost per system per year is \$62,793 and \$422,444 in LCC savings. This is one simple example of measuring

the value added for an incentive that may be introduced in a contract. The PM now has quantifiable justification for rewarding a contractor. The contractor's incentive to increase their profits by finding innovating means to improve reliability in the redesign of a subunit and cost cutting manufacturing measures to further increase the MTBF will contribute to overall operational availability of the weapon system.

3. Simulation Decision Support Tool Application

a. PM and Warfighter

In determining the point of diminishing returns for investing in the improvement of reliability, a simulation model can be used to reflect the contribution of an incremental increase in a subunit's MTBF to the system's operational availability. This additional decision support tool can be utilized by the PM to present to the warfighter the value added for them in operational availability, while using the spreadsheet model to reflect the financial justification to those approving budget requests. Using the simulation model, the PM can evaluate different scenarios in which one area of the weapon system is isolated to determine the value of improved reliability and a point of diminishing returns.

b. The Effect on Operational Availability by Outsourcing Organic I-Level Maintenance

(1) Baseline for Simulation Model: Assuming the PM has collected data that represents the MTBF of the three major subsections of the UAV system: the GCS, Ground Equipment, and the Air Vehicle. For purposes of demonstrating the ability to isolate one section and determine a point of diminishing returns in the investment of improved reliability, a listing of ten program runs are used for the testing. All three sections of the weapon system will have a base MTBF of 500 hours. The simulation model will be programmed to reflect a weapon system operating for 12 hours daily and a total of 1,000 hours for testing purposes.

(2) Calculating Operational Availability: If the PM incrementally increases the MTBF of the GCS by 50 hours for each of the ten program runs, depicted in Figure 3.1.1 in Appendix B, the simulation model will assist in determining the most effective MTBF rate to improve the operational availability and the point of diminishing returns. Running the simulation model, program run seven with an MTBF of 800 hours

for the GCS produces an average operational availability of 66%. This marks the highest improvement in operational availability, and the point of diminishing returns. Any further investment in reliability of this major section alone will not be productive to the warfighter. The investment required to improve the reliability by 300 hours can thereby be weighed with the effect on LCC with the spreadsheet model. This data, used with the spreadsheet model, will provide the PM the value added to the warfighter with an accurate cost computation.

4. Scenario Three Model Analysis

a. Scenario 3-a LCC Spreadsheet and Simulation Model Analysis

The most cost effective improvement in reliability must be calculated if the maintenance is outsourced. It is assumed that outsourcing the maintenance will also result in the subunits redesign to improve the MTBF. It is also assumed that each failure requires \$200 in transportation cost to and from the repair site. The incremental increase in MTBF for the portable GCS results in the decrease in the number of spare parts required to be maintained in inventory, a decrease in the number of failures per UAV and system per year, the total number of repair hours for the year, and the transportation cost. This cost calculation will demonstrate the value added with each incremental increase in reliability. Increasing the MTBF to 500 hours, the LCC for the system becomes \$22,836,902. This is a decrease of \$3,124,413 from the \$25,961,315 LCC for outsourcing the maintenance only to the contractor. This cost savings can potentially be the value of the improvement in reliability which can be used by the PM to assess the monetary incentive reward to the contractor. Any additional improvement in MTBF will be an opportunity for the contractor to receive a greater profit.

The PM is now better informed to measure the value added from the contractor and to make a determination of what to incentivize in the contract. Key to the program is the issue of reliability and the PM must weigh any improvement with the associated costs. If the PM wants to ascertain a target decrease in the TAT if the maintenance activity was outsourced, this is another variable that can further be isolated for study. Also, a measure of the impact on reliability and cost to the program resulting from a decrease in TAT will be assist the PM in making investment decisions. The

baseline has a total annualized spares cost of \$1,449,000 a year at a 21% annual inventory rate. Decreasing the TAT specifically for the portable GCS, the PM is able to quantify a point of diminishing returns. This decision support tool provides to the PM the ability to incrementally change this variable and see how each change will influence the total ownership cost equation.

b. Scenario 3-a Conclusion

Figure 3 in Appendix B demonstrates the complexity of the LCC equation for maintenance costs. The information need by the PM to make investment decisions that will affect the life of a program must be accurate and realistic. As shown in this scenario, when isolating the costs to outsource labor, this individual variable significantly affects the total maintenance costs, and LCC. The PM must be knowledgeable about the LCC equation and how each individual contributes to this cost. Understanding the return for each incremental improvement in reliability for the portable GCS, the PM will be able to justify the costs associated with each percentage increase in reliability and determine a point of diminishing returns. Examining an increase in reliability for the portable GCS to 500hrs MTBF, total maintenance costs are reduced by \$69,120, and total spares required is reduced from nine to four. Using the spreadsheet model in Figure 3 in Appendix B, the PM is able to determine that an MTBF of 460hrs, the spare parts level is reduced to four. Knowing this information, the PM is able to make an accurate assessment of the size of the logistical footprint that will be required to support. An important feature of this decision support tool, the PM will be able to determine the size of the logistical footprint, with associated costs, to support a weapon system.

c. Scenario 3-b Spreadsheet Model Analysis

The value added for decreasing the TAT alone must be measured in order to determine the worth of outsourcing the maintenance activity. Assuming the current TAT is 20 days, the annualized spare cost for the portable GCS is at \$189,000. The portable GCS is classified as a non-critical subunit and the spare parts protection level of 85% is required to be maintained. Each UAV weapon system contains two portable GCS units, at a cost of \$100,000 each. The baseline of a 20 day TAT requires nine spare parts to be maintained in inventory. These nine units, costing \$100,000 each, make up the

\$189,000 annualized spare costs. In order to determine the number of required spare parts, λ (1/MTBF), K (number of components), and T (time) must be identified. Time (T) is calculated using the ground equipment's monthly operating hours multiplied by the quotient of TAT in a 30 day period (20/30).

The equation $K \cdot \lambda \cdot T$ = average number of failures during the repair turnaround: $8 \cdot (1/200) \cdot 160 = 6.4$ failures during a 20 day TAT. This is used with the Poisson distribution table to determine the number of spare parts required to maintain a protection level of 85%. Decreasing the TAT by one day, to 19 days, $K \cdot \lambda \cdot T = 6.08$. This will still require nine spare parts to be maintained. A decrease in the number of spare parts does not take place until the TAT is reduced to 18 days. This will reduce the spare parts required to eight and decrease the total spare cost for the portable GCS to \$800,000 and an annualized cost of \$168,000. The total annualized spare cost will be reduced to \$1,428,000. This reduction of \$21,000 in total annualized spare costs decreases the total costs per system per year to \$3,837,984 with a further savings of \$141,278 to the LCC.

d. Scenario 3-b Conclusion

The new LCC for the weapon system is now \$25,820,037 as a result of outsourcing the maintenance activity and decreasing the TAT to 18 days. This incremental decrease in LCC resulting from a decrease in TAT will allow for the PM to justify a targeted TAT with the associated costs to incentivize a contract. One example of doing just that would be for the PM to offer the \$141,278 in program savings to the contractor for reward of reducing and maintaining a TAT of 18 days or less. If the contractor manages to further reduce the TAT, the additional costs savings to the LCC of the program can be rewarded to the contractor as additional profit. If the contractor does not meet this requirement, they will forego this cash incentive. Recognizing the minimal value added of decreasing TAT alone when maintenance is outsourced, the PM now has a quantified monetary reason to seek the improvement in MTBF in addition to a reduction in TAT for the portable GCS.

V. CONCLUSION AND RECOMMENDATIONS

A. MOTIVATION

To assist Program Managers and others in defense acquisitions, a decision support tool that analyzes the financial options available when making an investment decision would greatly improve the content of a contract. As stated in the introduction, there is no standard decision support tool or methodology that will do this for defense contracts. With the DoD in transition to a leaner, versatile organization, and an ever decreasing budget, the need to adopt business practices that capitalizes on the ROI of every tax dollar spent on programs to improve reliability is present. The importance and benefits of applying such a decision support tool in creating contracts exceed the short term financial impact associated with any program. The ROI in improvement in reliability as a result of applying the concepts associated with the models will reduce not only the total ownership costs, but will provide the warfighter a reliable weapon system with a minimum logistics footprint.

The models proposed in this project are intended to be a template for PMs to use and tailor to their specific program. The two spreadsheet models evaluate the cost impact on the LCC when a variable in the total Life Cycle Cost equation is isolated and adjusted to reflect the criteria within a contract. Our Large LCC spreadsheet encompasses a broad financial outlook that accounts for Manning, Training, O&M, and RDT&E, and maintenance costs. This model is intended to support the PM when attempting to quantify the various hidden cost that each contract may have. To account strictly for maintenance cost information, the Small LCC spreadsheet model is used to conduct the analysis. This model is used to isolate individual subcomponent costs to weigh the tradeoffs associated with outsourcing to a potential contractor. The simulation language, Arena, supports our simulation based model that depicts the impact on Operational Availability when a group of isolated variables receive an incremental increase in reliability. Under ten program runs, each with an incremental increase in reliability, the PM will be able to identify the point of diminishing returns in reliability. This information, coupled with the financial data of the spreadsheet models, will equip the PM

with the knowledge needed to create a robust contract that benefits the government, and the contractor.

To illustrate the use and benefits of the proposed models, our project evaluates three different hypothetical scenarios that represent dilemmas PMs may encounter when having to make investment decisions. By depicting the effects on LCC and operational readiness when cost and readiness parameters are changed, such as subcomponent MTBFs and TAT, the models are intended to be a decision support tool for PMs. We first analyze the reasons for creating a standard model and method to assist PMs in meeting the needs of the warfighters, minimizing costs, and the logistics footprint of a program. Next we summarize our findings from the analysis conducted using the proposed models. Finally we conclude with a recommendation for further research and development for a tool that will further assist the PM with identifying a method to improve reliability that will also establish a confidence level that contractors will be able to achieve and maintain the terms of the contract.

B. OVERVIEW

The Department of Defense does not have a standardized model that will allow PMs to assess the value of potential incentive options being considered for incorporation into a contract. The many financial legacy systems that are currently in use do not provide the services with a standardized application of measuring the worth of an incentivized contract. A decision support tool that can accurately measure the value added of these incentives will assist PMs to determine the most cost effective improvement in reliability for a program. The models we propose in this project demonstrate the applications of isolating one or many cost parameters, e.g., labor rate, MTBF, or manning levels, to determine the worth of an incentive for a program. This value is measured by the contribution to reliability and LCC for the program.

To demonstrate the potential of our models, our spreadsheets use data from the Army's Shadow UAV. This information provided the baseline of LCC and reliability to conduct our analysis. Three hypothetical scenarios were created to reflect the financial costs and effect on reliability when the baseline was changed under an incentivized

contract. We quantified the value additive of these incentives when subcomponent reliabilities or logistics support elements were changed. The value added was measured in terms of contribution to Operational Availability and LCC. Costs associated with manpower, training, RDTE, and O&M were taken into consideration to have a broad perspective when accounting for LCC. The intent of the models we proposed in this project was to have an in-depth perspective concerning costs associated with the size of the logistics footprint required to support a weapon system.

The first scenario depicted a situation in which the Intermediate Level maintenance activity was eliminated. The maintenance was divided among the Organizational and Depot level activities for the UAV program. The effects on LCC were computed as the percentage of maintenance responsibility was divided among the Organizational and Depot maintenance activities. The size of the logistics footprint required to support this weapon system was analyzed as the maintenance and manning was arranged to reflect the responsibility assumed under the proposed contract. Under this proposed contract scenario, the management of spare parts inventory would either be retained organically by the service or outsourced to the contractor.

The second scenario took a critical look at an incentivized contract that outsourced the Intermediate Level maintenance for individual subcomponents of a weapon system. The incentive for the contractor to improve reliability and receive a healthy profit in return was evaluated. The spreadsheet model provided maintenance costs data that would reflect this outsourcing for the PM seeking to improve the reliability of the subcomponent. The TAT was also analyzed for its contribution to reliability. A simulation based model was used to reflect the incremental increases in reliability to determine the point of diminishing returns. This model, used with the spreadsheet model, would provide the PM with cost data and effect on the Operational Availability of the weapon system.

The third and final scenario took a more in-depth analysis of outsourcing the Intermediate Level maintenance activity. The maintenance of a critical subcomponent or the entire weapon system was evaluated for outsourcing to the OEM. Manpower and

training costs were appraised when maintenance was outsourced and the costs of incremental increases in reliability weighed in their contribution to the LCC.

C. CONCLUSIONS

1. **Changing the maintenance structure from three to two maintenance activities can introduce cost savings without adversely effecting system reliability.**

The Large LCC model can assist the Program Manager to create a maintenance strategy that will provide cost savings for a program while maintaining the same level of subcomponent reliability.

2. **Cost savings from outsourcing spare parts management and transportation requirements can be isolated to determine the potential value for contract incentives.**

The Program Manager can use the Large LCC model to isolate major cost drivers of a weapon system. This information can further assist the Program Manager to make investment decisions that reduce operating costs without adversely effecting the contribution to the warfighter.

3. **Cost savings from outsourcing a single critical component or the entire weapon system can be isolated to determine the potential value of the incentive if the improvement is demonstrated by the OEM.**

The complex issue of changing multiple variables in the logistics and maintenance cycle (i.e., TAT, manning, training, and O&M costs) of one critical component or the entire weapon system reveals interdependent relationships between each one. By understanding this relationship, the PM is able to weigh the effect of each change and determine what the proposed outsourcing is worth in cost savings.

4. **The improvement of subcomponent reliability can be quantified and evaluated for possible incorporation into a contract incentive.**

The Small LCC and simulation based models we proposed in this project will develop a cost forecast of potential contract incentives to support the Program Manager's budget and estimate Operational Availability.

5. **Isolating and decreasing the turn-around-time reduces the amount of financial resources required to procure spare parts and decreases the logistics footprint needed to support a weapon system.**

The Small LCC model can be tailored to analyze how changing reliability parameters effect the Life Cycle Costs. The TAT was shown in Scenario 3-b how it can influence the size of the logistics footprint, which directly impacts the total Life Cycle Cost.

D. RECOMMENDATIONS

1. **The Department of Defense should adopt a standardized Total Life Cycle Cost model that will be interoperable for all branches of government to provide a uniformed cost analysis approach of contract incentives.**

The models proposed in this project present the first-step toward a good template for standardization. Our models attempt to isolate specific variables of the LCC equation to evaluate the benefits and costs being outsourced.

2. **Reliability should be included in the Key Performance Parameters to ensure funding is available to support the design and development of items of the Program to operate under specified conditions.**

Reliability is not another logistics term. Reliability is logistics. Investment in strong reliability parameters in the development stages of a weapon system will not only greatly reduce the Life Cycle Costs, but will also provide the warfighter with a valuable asset.

3. **Research should be conducted to establish a methodology that will provide the Program Manager a confidence level to ensure that contractors are capable of maintaining the terms of the contract.**

The models proposed in this project can be a valuable tool for a PM or other applicable agencies concerned with a cost analysis of the complex nature attempting to integrate incentives into government contracts. The models, coupled with the recommended methodology that establishes a confidence level of contractor support, will provide a robust decision support tool for the Program Manager.

APPENDIX A. UAV SYSTEM DESCRIPTION

1.2 SYSTEM DESCRIPTION

The Shadow system consists of several components to include: the Ground Control Station (GCS) and its related equipment, the Aerial Vehicle (AV), Modular Mission Payload (MMP), and communications. The Shadow is the Ground Maneuver Brigade Commander's primary day/night, Reconnaissance, Surveillance, and Target Acquisition (RSTA) system. The Shadow will provide the commander with a number of benefits to include enhanced enemy situational awareness, a target acquisition capability, battle damage assessment (BDA), and enhanced battle management capabilities (friendly situation and battlefield visualization). The combination of these benefits contribute to the Commanders ability to dominate situational awareness allowing him to maneuver to points of positional advantage with speed and precision in order to conduct decisive operations.

1.2.1 SYSTEM EQUIPMENT

The Shadow baseline system will consist of two Ground Control Stations (GCS), two Ground Data Terminals (GDTs), one Portable Ground Control Station (PGCS), one Portable Ground Data Terminal (PGDT) with Line of Sight (LOS) command and control links to the AV, four Remote Video Terminals (RVTs), four Modular Mission Payloads (MMPs), and four Air Vehicles (one is a spare) to support a wartime surge OPTEMPO, and Launch and Recovery (L/R) capability).

1.2.1.1 GROUND CONTROL STATION (GCS)

The GCS is the command and control center for the UAV Shadow System. It is utilized for pre-flight, launch, hand-off and recovery for operation of UAVs and payloads. The Shadow GCS consists of a HMMWV equipped with an improved S-788 Type II shelter with towing capability, generator, and Environment Control Unit (ECU). The Shadow GCS has two identical workstations capable of controlling the air vehicle and the payload, embedded training capabilities, and the necessary radios and equipment for both data and voice communications. (See Figures 1 and 2.)



Figure 1. GCS External View



Figure 2. GCS Interior View



Figure 3. GDT

1.2.1.2 GROUND DATA TERMINALS (GDT)

The GDT enables the data link to be sent between the GCS and the AV. It is composed of transceivers and controls a Differential GPS Base Station (with position self-determination), fiber optic link for remote operations of up to 400 meters, and directional antenna system for the primary command/telemetry and video links. The antenna system is designed for lightness, mobility, and air shipment. It consists of a 4-foot antenna dish, positioner/RF box, tripod, and control unit (see Figure 3). The GDT is generator powered.

1.2.1.3 PORTABLE GROUND CONTROL STATION (PGCS)

The PGCS is a portable ground control station that can perform preflight/take-off/launch/recovery operations. It mirrors the monitoring, control or mission planning function of the full GCS. It uses one monitor, lacks the video recording system, and has less range in the primary and video links due to the use of omni antennas as its primary data link. The PGCS can operate as a standalone system complete with appropriate powers source (primary and backup) or as a complimentary system coupled to the primary GCS with an umbilical. It consists of two cases (See Figure 4). Case 1 contains the processor, slot cards, and display. Case 2 contains components to perform external communications, intercom controls and the joystick.



Figure 4. Portable Ground Control Station

1.2.1.4 PORTABLE GROUND DATA TERMINAL (PGDT)

The PGDT provides the data link for the PGCS. The major components are common to the GDT (transceivers/receivers, etc.). The PGDT will have a range of at least 30 Km. The PGDT is generator powered.

1.2.1.5 MODULAR MISSION PAYLOADS (MMP)

The payload identified for initial use with the Shadow System is the Plug-in Optical Payload (POP) 200 (Figure 5). It is a day and night observation payload with tracker for UAV applications. The payload contains two imaging sensors, FLIR and TV. The FLIR provides the operator with medium wave infrared (MWIR) vision for target acquisition and tracking capability during day or night use. The color TV has the same role for daytime operation. The payload is contained in a single lightweight compact unit, which includes all the electronics necessary to operate the sensors, gimbals, and interfaces with the UAV avionics. The POP 200 is comprised of two sub-units, a gimballed turret, which is mounted on the UAV, and a plug-in sensors module. The sensors module slides into the turret and functions both as the sensor and as the pitch gimbal, with no need for any additional wiring, cables, or connectors. This approach allows the POP's sensor module to be changed or replaced in the field by one person. This operation takes only a few minutes to complete including testing after replacement of the module.

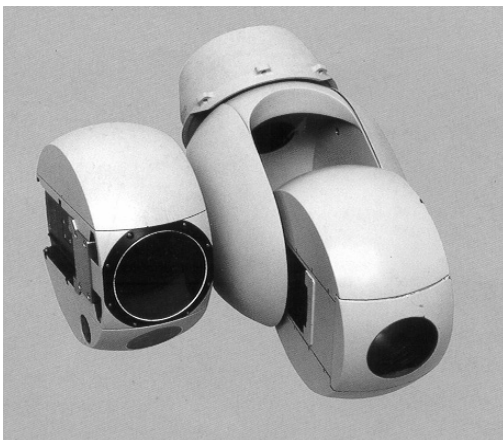


Figure 5. Payload



Figure 6. Air Vehicle

1.2.1.6 AIR VEHICLE (AV)

The AV is the airborne platform of the UAV Shadow System (see Figures 6). The AV is a high wing aircraft and serves as the “carrying device” for mission payloads. The GCS through the GDT remotely controls this system. AV will have on-station time of 4 hours at a 50Km range (objective is 3-4 hours at 200Km) with airborne mission equipment (MMP, transponder, etc.) included. The AV will have autonomous navigation capability and flight between multiple selected waypoints. Waypoints can be updated or reprogrammed from the controlling GCS.

1.2.1.7 LAUNCH AND RECOVERY EQUIPMENT

1.2.1.7.1 LAUNCHER

AV Launcher (see Figure 7) is a hydraulic launcher with an arrested shuttle for short take-off. It folds horizontally to fit into the compact transport configuration and is deployable by 2 people. The Launcher is generator powered.



Figure 7. Launcher

1.2.1.7.2 TACTICAL AUTOMATIC LANDING SYSTEM (TALS)

The TALS (see Figure 8) is an automatic beacon landing system that is independent of any GPS data and provides an automated landing touchdown and rollout for recovery. The TALS allows for the recovery of the Air Vehicle without an external pilot. For autoland, the operator initiates a sequence of commands that result in the desired automatic UAV guidance and control via the TALS. The pattern starts with the UAV returning to a hold point near the landing zone. The UAV will initiate an automatic hold sequence until personnel at the landing zone are in-place and ready for the vehicle to land. The operator then commands the AV into the Acquisition Window (AW). Next the operator commands the TALS to acquire and confirms transition to the TRACK mode. The AV continues into the Recovery Initiation Window (approximately 1 to 3 km final) and the operator invokes Autoland from the GCS. The TALS controls the AV down the glide slope to flare/touchdown/roll-out/stop. TALS will automatically abort following detection of a failure or by operator command to abort. The PGCS generator through the PGCS uninterruptible power supply (UPS) normally power the TALS. During initial entry, the TALS is powered from a TALS outlet on the GCS I/O panel. TALS has a battery pack for back-up.



Figure 8. TALS

1.2.1.7.3 ARRESTING GEAR

Arrested recovery (see Figure 9) makes use of a deployable arresting hook mounted on the underside of the AV and ground-based pendant cables attached to an arresting brake at each end. After landing, the arresting hook captures one of the cables and the arresting gear caliper brakes decelerate the AV to a stop within 15m.



Figure 9. Arresting Gear

1.2.1.7.4 PARACHUTE RECOVERY

The Shadow AV is equipped with a parachute in the event emergency recovery is necessary. The parachute is deployed by a signal from the GCS or PGCS or automatically deployed by predefined emergency situations. When fully deployed, the recovery parachute recovers the air vehicle upside down to prevent damage to the MMP.

1.2.1.7.5 REMOTE VIDEO TERMINAL (RVT)

The RVT (see Figure 10) is a stand-alone deployable ground unit that can track the AV and provide on-board payload sensor real-time video to a flat panel display.

Telemetric data received from the UAV provides information for overlay on the display to enhance the operator's situational awareness and to provide vital information related to targeting.

The RVT consists of two major components: the a field deployable Antenna Assembly with Directional Antenna and a Remote Terminal Assembly. The RVT is powered with AC power, if not available the HMMWV 24/28 VDC power can be used. The RVT has a battery pack which may be used as back-up power in case of AC loss. The RVT is a lightweight, portable, passive (receive only) unit operable from either a HMMWV or fixed base. It passively tracks a selected AV and displays Payload imagery from that AV, along with Date/Time Group (DTG) and navigation information. Displayed target coordinates and RVT coordinates can be used to determine how far a threat is from the RVT.

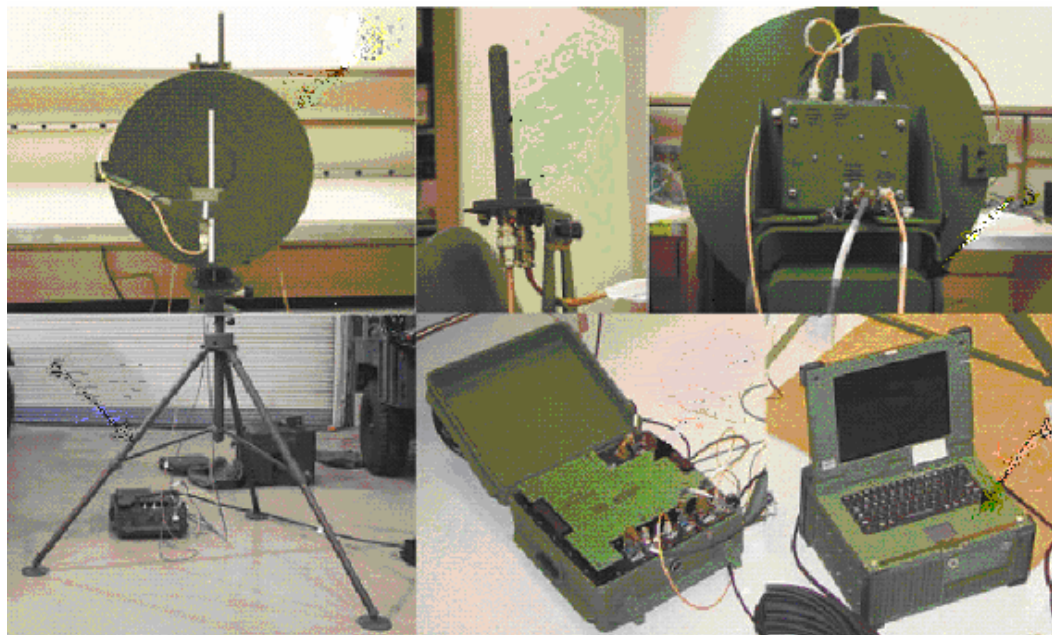


Figure 10: RVT System

APPENDIX B. LIST OF FIGURES

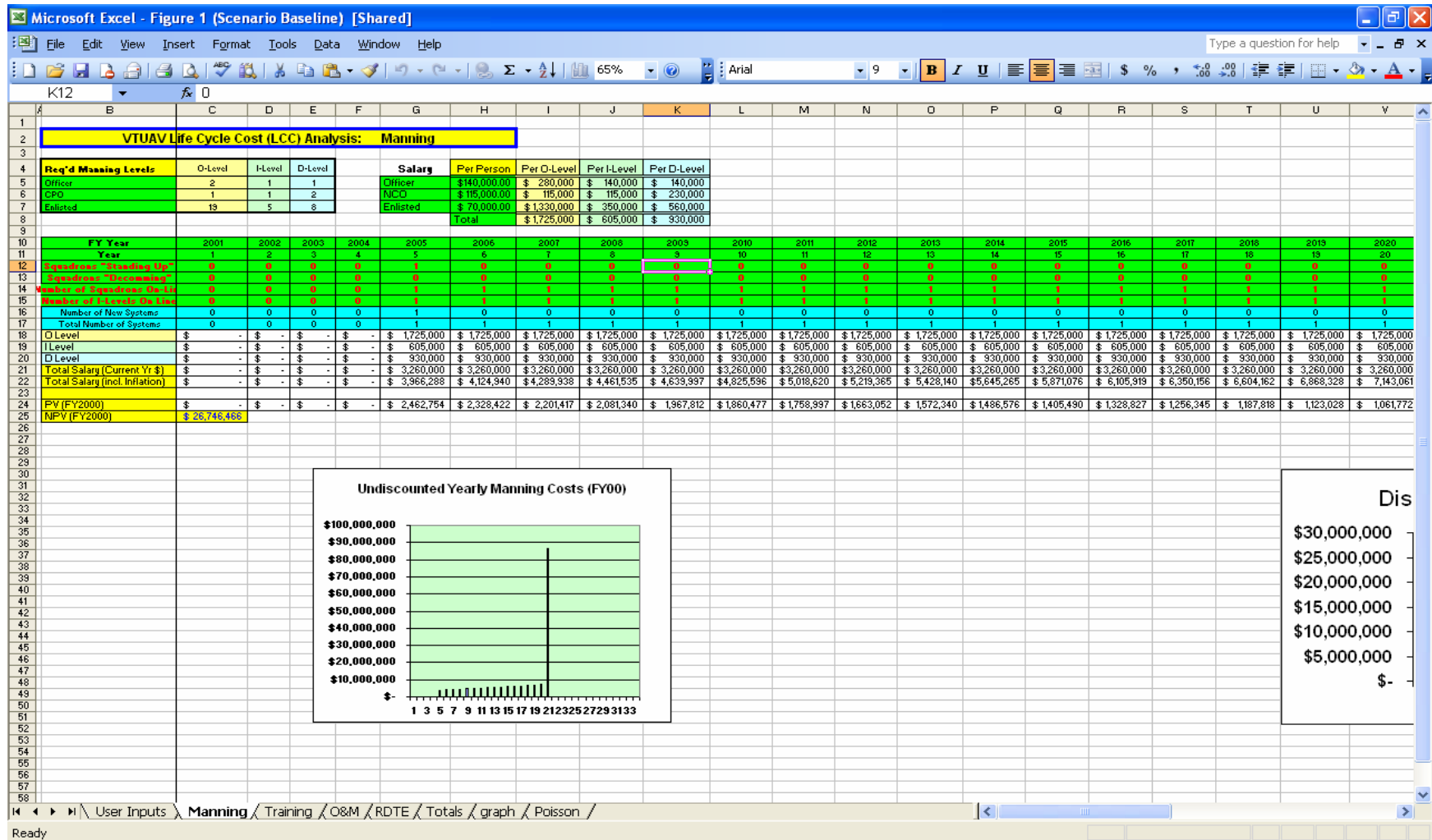


Figure 1.a: Baseline Scenario Manning Input Page

Microsoft Excel - Figure 1 (Scenario Baseline) [Shared]

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88																		

Ready

Figure 1.b: Baseline Scenario Training Input Page

[illegible]

Microsoft Excel - Figure 1 (Scenario Baseline) [Shared]														
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Type a question for help														
G12 =sysPERSquad*G7														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2		VTUAV Life Cycle Cost (LCC) Analysis: RDT&E and Production												
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User Inputs / Manning / Training / O&M / RDTE / Totals / graph / Poisson /														
Ready														

Figure 1.d: Baseline Scenario RDT&E Input Page

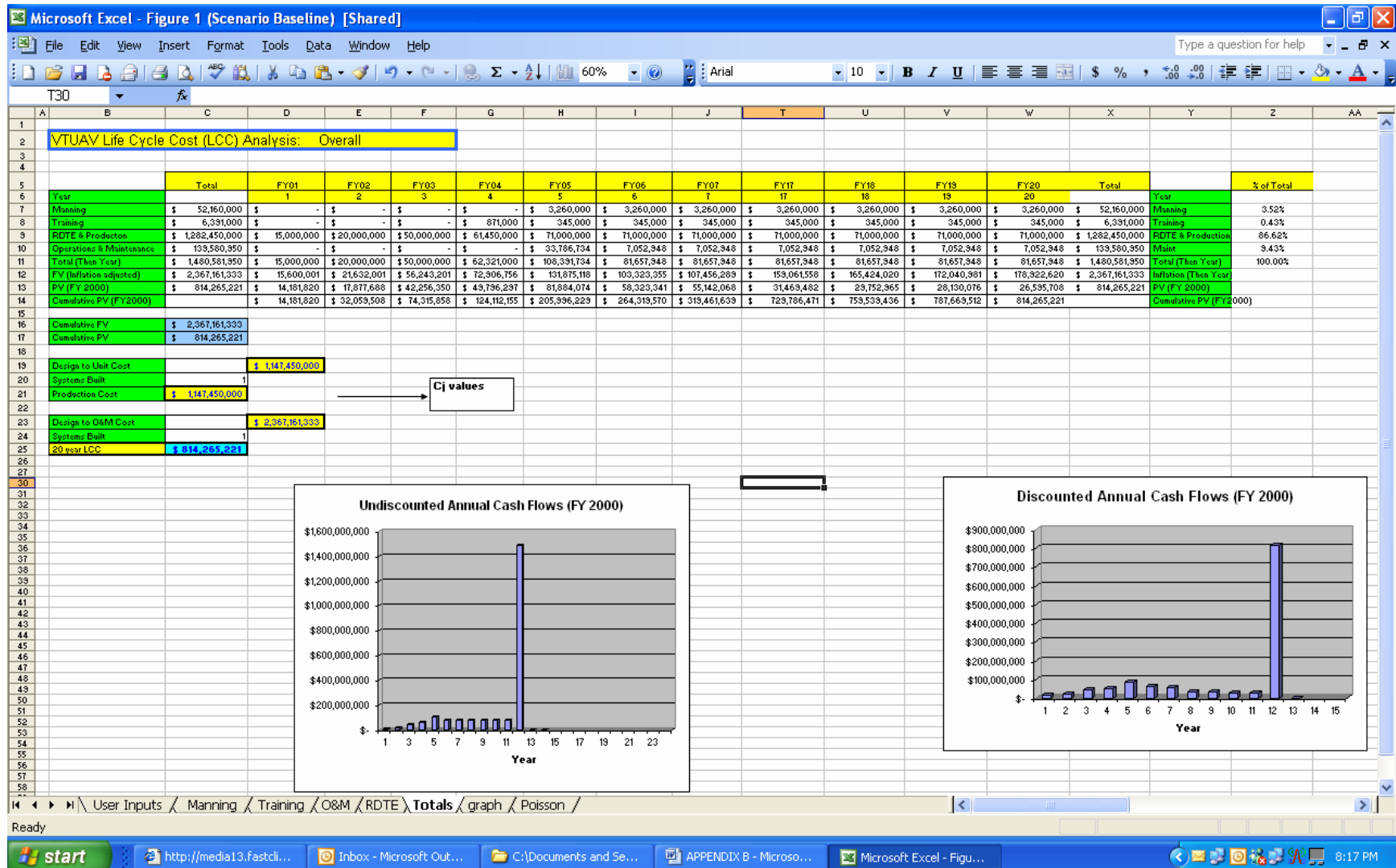


Figure 1.e: Baseline Scenario Totals Page

Microsoft Excel - Figure 1.1 (Scenario 1-a) [Shared]

File Edit View Insert Format Tools Data Window Help

T33

VTUAV Life Cycle Cost (LCC) Analysis: User Inputs

VTUAV Life Cycle Cost (LCC) Analysis: MTBF Inputs

General Inputs

Manning Inputs

Maintenance/Equipment Inputs

Training Inputs

Operational Inputs

RDTE & Production Inputs

Component Inputs

Reliability Factors (MTBF values in Column Q will be updated)

Component Code Name

Component Name

MTBF Code Name

MTBF Base

updated MTBF

Failure Rate (λ)

Critical/NonCritical

Protective Lease

Unit Cost

LIFE CYCLE COSTS

\$ 311,459,139

Red Numbers ⇒ Inputs

Blue Numbers ⇒ Computed

User Inputs / Manning / Training / O&M / RDTE / Totals / graph / Poisson /

Ready

Figure 1.1: Scenario 1-a User Input Page

Microsoft Excel - 0 Figure 1.2 (Scenario 1.b) [Shared]												
File Edit View Insert Format Tools Data Window Help												
Type a question for help												
75%												
Arial												
E4												
A	B	C	D	E	F	G	H	I	J	K	L	M
4	Per I-Level		Failures/System	Required Spares(Norm)		Annual I-Level	Initial Spare Purchase	Annual Depot	Annual O-Level	Annualized Spare		
5	Ground Control Station	MTBF	per Year	Norm	Poisson	Unit Cost	Maint Costs /	Cost per Sys	Maint Cost / Sys	Maint Cost / Sys	Cost	
6	HMM/V	750	8	3	2	\$ 75,000	\$ -	\$ 225,000	\$ 34,560	\$ 768	\$ 47,250	
7	Power Generator	214	28	6	6	\$ 50,000	\$ -	\$ 300,000	\$ 121,121	\$ 2,692	\$ 63,000	
8	Environmental Control Unit	2103	4	2	1	\$ 25,543	\$ -	\$ 51,086	\$ 12,325	\$ 274	\$ 10,728	
9	Guidance & Control Work station	544	24	3	3	\$ 43,566	\$ -	\$ 130,698	\$ 47,647	\$ 1,059	\$ 27,447	
10	Radio Equipment for Data and Voice	956	16	2	1	\$ 5,522	\$ -	\$ 11,044	\$ 30,280	\$ 673	\$ 2,319	
11	Ground Data Terminal	1514	4	2	1	\$ 51,372	\$ -	\$ 102,744	\$ 17,120	\$ 390	\$ 21,576	
12												
13	Other Ground Equip			Norm	Poisson							
14	Launcher	500	2	1	1	\$ 50,000	\$ -	\$ 50,000	\$ 5,184	\$ 115	\$ 10,500	O-I-D level Cost per System
15	Portable Ground Control Station	499	6	1	#N/A	\$ 9,206	\$ -	\$ 9,206	\$ 5,194	\$ 115	\$ 1,933	\$ 415,746
16	Portable Ground Data Terminal	499	6	1	#N/A	\$ 9,206	\$ -	\$ 9,206	\$ 5,194	\$ 115	\$ 1,933	
17	Tactical Automatic Landing System	1070	3	1	1	\$ 4,300	\$ -	\$ 4,300	\$ 2,422	\$ 54	\$ 903	
18	Remote Video Terminal	1514	8	1	#N/A	\$ 9,548	\$ -	\$ 9,548	\$ 1,712	\$ 38	\$ 2,005	
19												
20	AV			Norm	Poisson							Initial Spares Cost per I-Level
21	Navigation/Avionics	3212	4	1	1	\$ 88,237	\$ -	\$ 88,237	\$ 8,406	\$ 187	\$ 18,530	\$ 1,985,701
22	Engine	1187	8	2	2	\$ 428,271	\$ -	\$ 856,542	\$ 22,746	\$ 505	\$ 179,874	
23	Propeller	1323	8	2	2	\$ 6,526	\$ -	\$ 13,052	\$ 20,408	\$ 454	\$ 2,741	
24	Modular Mission Payloads (MMP)	746	12	2	2	\$ 57,519	\$ -	\$ 115,038	\$ 36,193	\$ 804	\$ 24,158	Cost per System
25	Parachute Recovery	746	12	2	2	\$ 5,000	\$ -	\$ 10,000	\$ 36,193	\$ 804	\$ 2,100	\$ 415,746
26												
27	Maintenance Shipments per System per year		153					\$ 1,985,701	\$ 406,708	\$ 9,038	\$ 416,997	
28	(Transportation cost)											
29												
30												
31												
32												
33												
34	FY Year	2001	2002	2007	2008	2009	2010	2011	2012	2013	2014	2015
35	Year	1	2	7	8	9	10	11	12	13	14	15
36	Squadrons "Standing Up"	0	0	0	0	0	0	0	0	0	0	0
37	Squadrons "Decommissioning"	0	0	0	0	0	0	0	0	0	0	0
38	Number of Squadrons	0	0	1	1	1	1	1	1	1	1	1
39	Number of New I-Levels	0	0	0	0	0	0	0	0	0	0	0
40	Number of Systems On Line	0	0	1	1	1	1	1	1	1	1	1
41	Number of New Systems	0	0	0	0	0	0	0	0	0	0	0
42	Total Number of Systems	0	0	1	1	1	1	1	1	1	1	1
43												
44	I-Level Activation Cost	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
45	I-Level Operating Cost	\$ -	\$ -	\$ 6,000,000	\$ 6,000,000	\$ 6,000,000	\$ 6,000,000	\$ 6,000,000	\$ 6,000,000	\$ 6,000,000	\$ 6,000,000	\$ 6,000,000
46	Transportation Cost	\$ -	\$ -	\$ 30,600	\$ 30,600	\$ 30,600	\$ 30,600	\$ 30,600	\$ 30,600	\$ 30,600	\$ 30,600	\$ 30,600
47	POL	\$ -	\$ -	\$ 360,000	\$ 360,000	\$ 360,000	\$ 360,000	\$ 360,000	\$ 360,000	\$ 360,000	\$ 360,000	\$ 360,000
48	Initial Spare Purchase	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
49	Annual Inventory Spare Cost	\$ -	\$ -	\$ 416,997	\$ 416,997	\$ 416,997	\$ 416,997	\$ 416,997	\$ 416,997	\$ 416,997	\$ 416,997	\$ 416,997
50	Maintenance Costs	\$ -	\$ -	\$ 415,746	\$ 415,746	\$ 415,746	\$ 415,746	\$ 415,746	\$ 415,746	\$ 415,746	\$ 415,746	\$ 415,746
51	Disposal Costs	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
52	Total (FY2000)	\$ -	\$ -	\$ 7,223,343	\$ 7,223,343	\$ 7,223,343	\$ 7,223,343	\$ 7,223,343	\$ 7,223,343	\$ 7,223,343	\$ 7,223,343	\$ 7,223,343
53	Inflation (Then Year)	\$ -	\$ -	\$ 9,505,427	\$ 9,885,644	\$ 10,281,070	\$ 10,692,313	\$ 11,120,005	\$ 11,564,806	\$ 12,027,398	\$ 12,508,494	\$ 13,008,833
54	PV (FY2000)	\$ -	\$ -	\$ 3,798,723	\$ 3,465,502	\$ 3,161,511	\$ 2,884,185	\$ 2,631,186	\$ 2,400,381	\$ 2,189,821	\$ 1,997,731	\$ 1,822,492
55	NPV	\$ 41,311,733										
56												
User Inputs / Manning / Training / O&M / RDTE / Totals / graph / Poisson /												
Ready												
Sum=63202740.31												

Figure 1.2: Scenario 1-b O&M Page

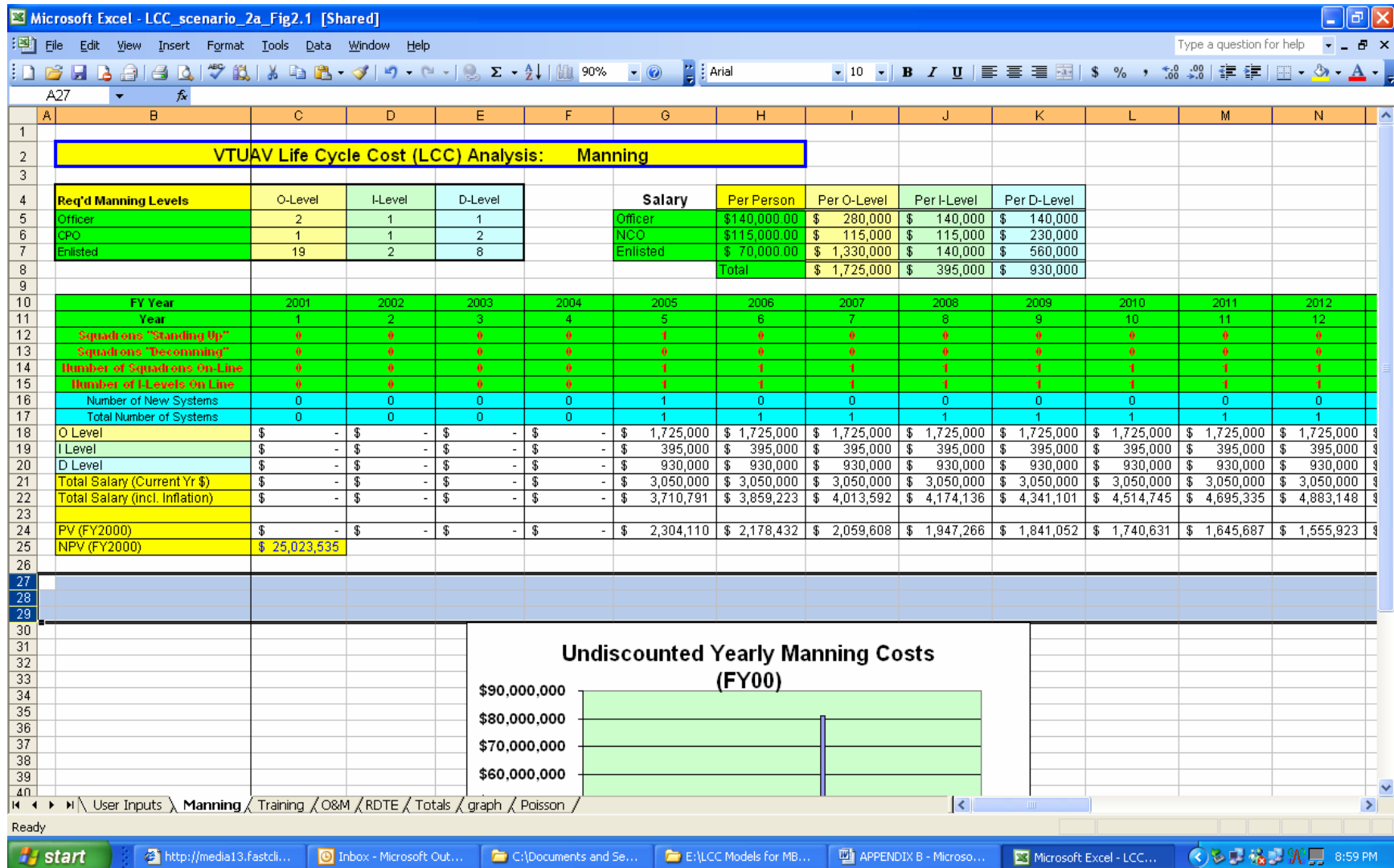


Figure 2.1.a: Scenario 2-a Manning Page

Microsoft Excel - LCC_scenario_2a_Fig2.1 [Shared]													
File Edit View Insert Format Tools Data Window Help													
Type a question for help													
A43													
9	A	B	C	D	E	F	G	H	I	J	K	L	M
10		Personnel Requiring Training											
11													
12		FY Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
13		Year	1	2	3	4	5	6	7	8	9	10	11
14		Squadrons "Standing Up"	0	0	0	0	1	0	0	0	0	0	0
15		Squadrons "Decomming"	0	0	0	0	0	0	0	0	0	0	0
16		Number of Squadrons	0	0	0	0	1	1	1	1	1	1	1
17		Number of I-Levels On Line	0	0	0	0	1	1	1	1	1	1	1
18		Number of New Systems	0	0	0	0	1	0	0	0	0	0	0
19		Total Number of Systems	0	0	0	0	1	1	1	1	1	1	1
44													
45		Funds Required for Training											
46													
47		FY Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
48		Year	1	2	3	4	5	6	7	8	9	10	11
49		O-Level Basic											
50		Officer	\$ -	\$ -	\$ -	\$ 32,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000
51		Chief Petty Officers	\$ -	\$ -	\$ -	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000
52		Junior Enlisted	\$ -	\$ -	\$ -	\$ 304,000	\$ 64,000	\$ 64,000	\$ 64,000	\$ 64,000	\$ 64,000	\$ 64,000	\$ 64,000
53		O-Level Advanced											
54		Officer	\$ -	\$ -	\$ -	\$ 30,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000
55		Chief Petty Officers	\$ -	\$ -	\$ -	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000
56		Junior Enlisted											
57		I-level Basic											
58		Officer	\$ -	\$ -	\$ -	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000
59		Chief Petty Officers	\$ -	\$ -	\$ -	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000
60		Junior Enlisted	\$ -	\$ -	\$ -	\$ 32,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000
61		I-Level Advanced											
62		Officer	\$ -	\$ -	\$ -	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000
63		Chief Petty Officers	\$ -	\$ -	\$ -	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000
64		Junior Enlisted											
65		D-Level Basic											
66		Officer	\$ -	\$ -	\$ -	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000
67		Chief Petty Officers	\$ -	\$ -	\$ -	\$ 32,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000	\$ 16,000
68		Junior Enlisted	\$ -	\$ -	\$ -	\$ 128,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000	\$ 32,000
69		D-Level Adv											
70		Officer	\$ -	\$ -	\$ -	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000
71		Chief Petty Officers	\$ -	\$ -	\$ -	\$ 30,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000	\$ 15,000
72		Junior Enlisted	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
73													
74		Total (Current \$)	\$ -	\$ -	\$ -	\$ 743,000	\$ 329,000	\$ 329,000	\$ 329,000	\$ 329,000	\$ 329,000	\$ 329,000	\$ 329,000
75		Inflation (Then Year)	\$ -	\$ -	\$ -	\$ 869,206	\$ 400,280	\$ 416,291	\$ 432,943	\$ 450,260	\$ 468,271	\$ 487,001	\$ 506,481
76		PV (FY 2000)	\$ -	\$ -	\$ -	\$ 593,680	\$ 248,543	\$ 234,986	\$ 222,169	\$ 210,051	\$ 198,593	\$ 187,761	\$ 177,520
77		NPV	\$ 3,292,960										
78													
User Inputs / Manning / Training / O&M / RDTE / Totals / graph / Poisson /													
Ready Sum=0													

Figure 2.1.b: Scenario 2-a Training Page

Microsoft Excel - LCC_scenario_2a_Fig2.1 [Shared]												
File Edit View Insert Format Tools Data Window Help												
Type a question for help												
S28												
A	B	C	D	E	F	G	H	I	J	K	L	
1												
2	VTUAV Life Cycle Cost (LCC) Analysis: Maintenance											
3												
4	Per I-level		Failures/System				k*lambda*t / sqn	Required Spares(Norm)			Annual I-Level	
5	Ground Control Station	MTBF	per Year	λ	Protection Level	Op Hr in Ave TAT	during TAT	Norm	Poisson	Unit Cost	Maint Costs / Sy	
6	HMMVV	750	8	0.00133	Critical	184.0	0.49	2	2	\$ 75,000	\$ 17,	
7	Power Generator	214	28	0.00467	Critical	184.0	1.72	4	4	\$ 50,000	\$ 60,	
8	Environmental Control Unit	2103	4	0.00048	Critical	184.0	0.17	1	1	\$ 25,543	\$ 6,	
9	Guidance & Control Workstaion	544	24	0.00184	Critical	184.0	0.68	3	2	\$ 43,566	\$ 23,	
10	Radio Equipment for Data and Voice	856	16	0.00117	NonCritical	184.0	0.43	2	1	\$ 5,522	\$ 15,	
11	Ground Data Terminal	1514	4	0.00066	NonCritical	184.0	0.24	1	1	\$ 51,372	\$ 8,	
12												
13	Other Ground Equip							Norm	Poisson			
14	Launcher	500	2	0.00200	Critical	36.8	0.07	1	1	\$ 50,000	\$ 2,	
15	Portable Ground Control Station	499	6	0.00200	NonCritical	36.8	0.07	1	#N/A	\$ 9,206	\$ 2,	
16	Portable Ground Data Terminal	499	6	0.00200	NonCritical	36.8	0.07	1	#N/A	\$ 9,206	\$ 2,	
17	Tactical Automatic Landing System	1070	3	0.00093	Critical	36.8	0.03	1	#N/A	\$ 4,300	\$ 1,	
18	Remote Video Terminal	1514	8	0.00066	Critical	36.8	0.02	1	#N/A	\$ 9,548	\$	
19												
20	AV							Norm	Poisson			
21	Navigation/Avionics	3212	4	0.00031	Critical	95.8	0.12	1	1	\$ 88,237	\$ 4,	
22	Engine	1187	8	0.00084	Critical	127.1	0.43	2	2	\$ 428,271	\$ 11,	
23	Propeller	1323	8	0.00076	Critical	95.8	0.29	2	1	\$ 6,526	\$ 10,	
24	*Modular Mission Payloads (MMP)	746	12	0.00134	NonCritical	95.8	0.51	2	1	\$ 57,519	\$ 18,	
25	Parachute Recovery	746	12	0.00134	NonCritical	95.8	0.51	2	1	\$ 5,000	\$ 18,	
26												
27	Maintenance Shipments per System per year		153								\$ 203,	
28	(Transportation cost)											
29												
30												
31												
32												
33												
34	FY Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
35	Year	1	2	3	4	5	6	7	8	9	10	
36	Squadrons "Standing Up"	0	0	0	0	1	0	0	0	0	0	
37	Squadrons "Decomming"	0	0	0	0	0	0	0	0	0	0	
38	Number of Squadrons	0	0	0	0	1	1	1	1	1	1	
39	Number of New I-Levels	0	0	0	0	1	0	0	0	0	0	
40	Number of I-Levels On Line	0	0	0	0	1	1	1	1	1	1	
41	Number of New Systems	0	0	0	0	1	0	0	0	0	0	
42	Total Number of Systems	0	0	0	0	1	1	1	1	1	1	
User Inputs \ Manning \ Training \ O&M \ RDTE \ Totals \ graph \ Poisson \												
Ready												
start http://media13.fastcl... Inbox - Microsoft Out... C:\Documents and Se... E:\LCC Models for MB... APPENDIX B - Microso... Microsoft Excel - LCC... 9:04 PM												

Figure 2.1.c: Scenario 2-a O&M Page

Microsoft Excel - LCC_scenario_2a_MTBF_Fig2.2 [Shared]												
File Edit View Insert Format Tools Data Window Help												
Type a question for help												
S36												
A	B	C	D	E	N	O	P	Q	R	S	T	U
2												
3	General Inputs				Component Inputs							
4												
5	Capital Discount Rate	10%			Reliability Factors (MTBF values in Column Q will be updated)							
6	Inflation Rate	4%										
7	Manpower Attrition Rate	20%			MTBF Criticality Factor I	1	for critical components					
8	Peace Time Loss Risk (Min/Max/Delta)	2%	7%	5%	MTBF Criticality Factor II	1	for noncritical components					
9	Contingency Loss Risk (Min/Max/Delta)	15%	30%	15%								
10	Contingency Chance	15%										
11	Number of Reconnaissance, Surveillance and Targeting Squadrons RSTA	1										
12	Number of Systems/Squadron	1			Component Code Name	Component Name	MTBF Code Name	MTBF (base)	updated MTBF	Failure Rate (λ)	Critical/NonCritical	Protection Level
13	Officer Salary	\$	140,000		HUMMER	HMMWV	MTBFHMMWV	750	750	0.001333	Critical	0.95
14	CPO Salary	\$	115,000		Power Generator	PG	MTBFPG	214	214	0.004673	Critical	0.95
15	E-1 to E-6 Salary	\$	70,000		Environmental Control Unit	ECU	MTBFECU	2103	2103	0.000476	Critical	0.95
16	Life Years of Program	20			Guidance & Control Workstation	GC	MTBFGC	544	544	0.001838	Critical	0.95
17					Radio Equipment for Data and Voice	RAD	MTBFRAD	856	856	0.001168	NonCritical	0.85
18	Training Inputs				Ground Data Terminal	GDT	MTBFGDT	1514	1514	0.000661	NonCritical	0.85
19					Launcher	LCR	MTBFLCR	500	500	0.002000	Critical	0.95
20	Basic Training Costs / week	\$	1,600		Portable Ground Control Station	PGCS	MTBFPGCS	499	499	0.002000	NonCritical	0.85
21	Advance Training Costs / week	\$	3,000		Portable Ground Data Terminal	PGDT	MTBFPGDT	499	499	0.002000	NonCritical	0.85
22					Tactical Automatic Landing System	TALS	MTBFTALS	1070	1070	0.002000	Critical	0.95
23					Remote Video Terminal	RVT	MTBFRVT	1514	1514	0.002000	Critical	0.95
24					Navigation/Avionics	NAVAV	MTBFNAVAV	3212	3212	0.000311	Critical	0.95
25	Basic UAV	10	10	10	Engine	ENG	MTBFENG	1500	1500	0.000667	Critical	0.95
26												
27	Advanced UAV	5	5	0	Propeller	PROP	MTBFPROP	1323	1323	0.000756	Critical	0.95
28	I-Level Basic Maint. Training	20	20	10	Modular Mission Payload	MMP	MTBFMMP	746	746	0.001340	NonCritical	0.85
29	I-Level Adv Maint. Training	5	5	0	Parachute Recovery	PAR	MTBFPAR	200	200	0.005000	NonCritical	0.85
30	Squadron HQ Basic Training	10	10	10								
31	Squadron HQ Adv Training	5	5	0								
32												
33	Operational Inputs				LIFE CYCLE COSTS							
34												
35					\$ 334,099,353							
36	POL Costs/Fit Hour	\$	60.00									
User Inputs / Manning / Training / O&M / RDTE / Totals / graph / Poisson /												
Ready												

Figure 2.2: Scenario 2-a User Input Page w/Engine MTBF Increase

Microsoft Excel - LCC_scenario_2b_Fig2.3 [Shared]

File Edit View Insert Format Tools Data Window Help

Type a question for help

S36 fx

VTUAV Life Cycle Cost (LCC) Analysis: User Inputs

VTUAV Life Cycle Cost (LCC)

General Inputs

Manning Inputs

Maintenance Equipment Inputs

Training Inputs

Operational Inputs

RDTE & Production Inputs

Outsourced TAT For Components

LIFE CYCLE COSTS

\$ 336,972,573

Red Numbers => Inputs
Blue Numbers => Computed

User Inputs / Manning / Training / O&M / RDTE / Totals / graph / Poisson /

Ready

Figure 2.3: Scenario 2-b User Input Page

Microsoft Excel - LCC_scenario_2b_Fig2.3 [Shared]														
File Edit View Insert Format Tools Data Window Help														
Type a question for help														
K3 fx 75% Arial CE 9 B I U														
A	B	C	D	E	F	G	H	I	J	K	L	M	N	
1	VTUAV Life Cycle Cost (LCC) Analysis: User Inputs													VTUAV Life Cycle Cost (LCC
2														
3	General Inputs					Manning Inputs								
4														
5	Capital Discount Rate		10%										Reliability Factors (MTBF values in Column Q will	
6	Inflation Rate		4%											
7	Manpower Attrition Rate		20%			Officers	2	6	1				MTBF Criticality Factor I	
8	Peace Time Loss Risk (Min/Max/Delt		2%	7%	5%	CPOs	1		2				MTBF Criticality Factor II	
9	Contingency Loss Risk (Min/Max/Delt		15%	30%	15%	E-1 to E-6	19		8					
10	Contingency Chance					Maintenance Equipment Inputs								
11	Number of Reconnaissance, Surveillance and Targeting Squadrons RSTA													
12	Number of Systems/Squadron													
13	Officer Salary		\$ 140,000			Number of AVs per System							Component Code Name	
14	CPO Salary		\$ 115,000			Number of GCS per System							HUMMER	
15	E-1 to E-6 Salary		\$ 70,000			Number of Items in each GCS							Power Generator	
16	Life Years of Program		20			Number of GDT per System							Environmental Control Unit	
17						Number of RVT per System							Guidance & Control Workstation	
18	Training Inputs					AV Unit Cost							Radio Equipment for Data and Voice	
19						Ground Control Equip Cost							Ground Data Terminal	
20	Basic Training Costs / week		\$ 1,600			Test Equipment (I-Level) Cost							Launcher	
21	Advance Training Costs / week		\$ 3,000			Critical Protection Level							Portable Ground Control Station	
22						Non-Critical Protection Level							Portable Ground Data Terminal	
23						TAT (days) ~ I-Level							Tactical Automatic Landing System	
24						TAT (days) ~ D-Level							Remote Video Terminal	
25						Number of I-Levels							Navigation/Avionics	
26						I-Levels/Squadron							Engine	
27						Failures Repaired At O-Level							Propeller	
28						Failures Repaired At I-Level							Modular Mission Payload	
29						Failures Repaired At D-Level							Parachute Recovery	
30						Spare Level Factor								
31						Systems/I-Level								
32						I-Level Activation Cost								
33						I-Level Operating Cost/yr								
34						Depot Repair Cost								
35						Transportation \$/Shipment								
36						RDTE & Production Inputs								
37														
38						Production Line Open Costs								
39						RDTE Year 1								
40						RDTE Year 2								
41						RDTE Year 3								
42						RDTE Year 4								
43						Number of Years Line Open								
44						Cost/Year of Production								
User Inputs / Manning / Training / O&M / RDTE / Totals / graph / Poisson /														
Ready														

Figure 2.4: Scenario 2-b User Input Page w/20% Reduction in I Level Operating Cost

Microsoft Excel - Figure 3 (2) [Read Only]

FileEditViewInsertFormatToolsDataWindowHelp

Type a question for help

O46

67%

Arial10

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	VTUAV Case Study																						
2																							
3	No of Squadrons	1																					
4	No of UAV systems per squadron	1																					
5	No of Air Vehicles per	4																					
6	No of Ground Control stations per system	2																					
7	Ground Equip Monthly Op Hrs	240 hrs																					
8	AV Flying Hrs/Vehicle/mo	125 hrs																					
9	Art/Land S/Land Rec Monthly Op Hrs	48 hrs		20% of Ground Equipment Hours																			
10	Repair Turnaround Time	20 days		Proposed TAT	20	days																	
11	Protection Level for Critical Components	0.85																					
12	Protection Level for non-Critical Components	0.85																					
13	Hourly charge for repair including material cost	\$100		Proposed hourly rate	\$500																		
14	Transportation per mile	\$200																					
15	Annual failure rate	0.21																					
16	Capital Discount rate	0.1																					
17	Life Cycle	20 years																					
18	Per I-Level																						
19	Ground Control Station (GCS) Components	MTBF	Unit Cost	Protection Level	# of units per UAV	# of units per system	Op Hr during TAT	Avg Failure s during TAT	Required spares (Using Poisson)	Tot Spare cost	Annualized spare cost	Failure s/ UAV /yr	of failure s per gr system	Avg repair time (hrs)	Tot num of for repair hrs	Tot repair cost	Transportation Cost						
20	RTW/RTG	200	\$ 100,000	NonCritical	0.85	1	4	160.0	3.20	5	\$ 500,000	\$ 105,000	14.4	57.6	10	576	\$ 57,600	\$ 11,520					
21	ECU Environmental Cont Unit	500	\$ 100,000	Critical	0.95	1	4	160.0	1.28	3	\$ 300,000	\$ 63,000	5.8	23.0	10	230	\$ 23,040	\$ 4,608					
22	Power Generator	500	\$ 100,000	Critical	0.95	1	4	160.0	1.28	3	\$ 300,000	\$ 63,000	5.8	23.0	10	230	\$ 23,040	\$ 4,608					
23	Guidance & Control Work Sta	200	\$ 100,000	NonCritical	0.85	2	8	160.0	6.40	9	\$ 900,000	\$ 189,000	14.4	115.2	10	1152	\$ 115,200	\$ 23,040					
24	Data & Voice Radio Comms	200	\$ 100,000	NonCritical	0.85	2	8	160.0	6.40	9	\$ 900,000	\$ 189,000	14.4	115.2	10	1152	\$ 115,200	\$ 23,040					
25	Portable GCS	200	\$ 100,000	NonCritical	0.85	2	8	160.0	6.40	9	\$ 900,000	\$ 189,000	14.4	115.2	10	1152	\$ 115,200	\$ 23,040					
26	Ground Data Terminals (GDT)	500	\$ 100,000	Critical	0.95	2	8	160.0	2.56	5	\$ 500,000	\$ 105,000	5.8	46.1	10	461	\$ 46,080	\$ 9,216					
27	Portable GDT	200	\$ 100,000	NonCritical	0.85	1	4	160.0	3.20	5	\$ 500,000	\$ 105,000	14.4	57.6	10	576	\$ 57,600	\$ 11,520					
28																							
29	Other Ground Equip																						
30	Launch & Recovery System	500	\$ 100,000	Critical	0.95	1	4	32.0	0.26	1	\$ 100,000	\$ 21,000	5.8	23.0	20	461	\$ 46,080	\$ 4,608					
31	RYT Remote Video Terminal	200	\$ 100,000	NonCritical	0.85	4	16	32.0	2.56	4	\$ 400,000	\$ 84,000	14.4	230.4	20	4608	\$ 460,800	\$ 46,080					
32	TALS Tactical Auto Landing S	200	\$ 100,000	NonCritical	0.85	4	16	32.0	2.56	4	\$ 400,000	\$ 84,000	14.4	230.4	20	4608	\$ 460,800	\$ 46,080					
33																							
34	AV																						
35	Navigation/Avionics	500	\$ 100,000	Critical	0.95	1	4	83.3	0.67	2	\$ 200,000	\$ 42,000	5.8	23.0	10	230	\$ 23,040	\$ 4,608					
36	Engine	500	\$ 100,000	Critical	0.95	1	4	83.3	0.67	2	\$ 200,000	\$ 42,000	5.8	23.0	10	230	\$ 23,040	\$ 4,608					
37	Propeller	500	\$ 100,000	Critical	0.95	1	4	83.3	0.67	2	\$ 200,000	\$ 42,000	5.8	23.0	10	230	\$ 23,040	\$ 4,608					
38	MMF Modular Mission Payload	200	\$ 100,000	NonCritical	0.85	1	4	83.3	1.67	3	\$ 300,000	\$ 63,000	14.4	57.6	10	576	\$ 57,600	\$ 11,520					
39	Parachute Recovery	200	\$ 100,000	NonCritical	0.85	1	4	83.3	1.67	3	\$ 300,000	\$ 63,000	14.4	57.6	10	576	\$ 57,600	\$ 11,520					
40																							
41											\$ 1,449,000					\$ 2,165,760	\$ 244,224						
42	Total cost per system per year		\$ 3,958,984	per yr																			
43																							
44	Total Annual cost		\$ 3,958,984																				
45																							
46	Total Life Cycle Cost		\$25,961,315																				
47	UAV Poisson																						

Ready

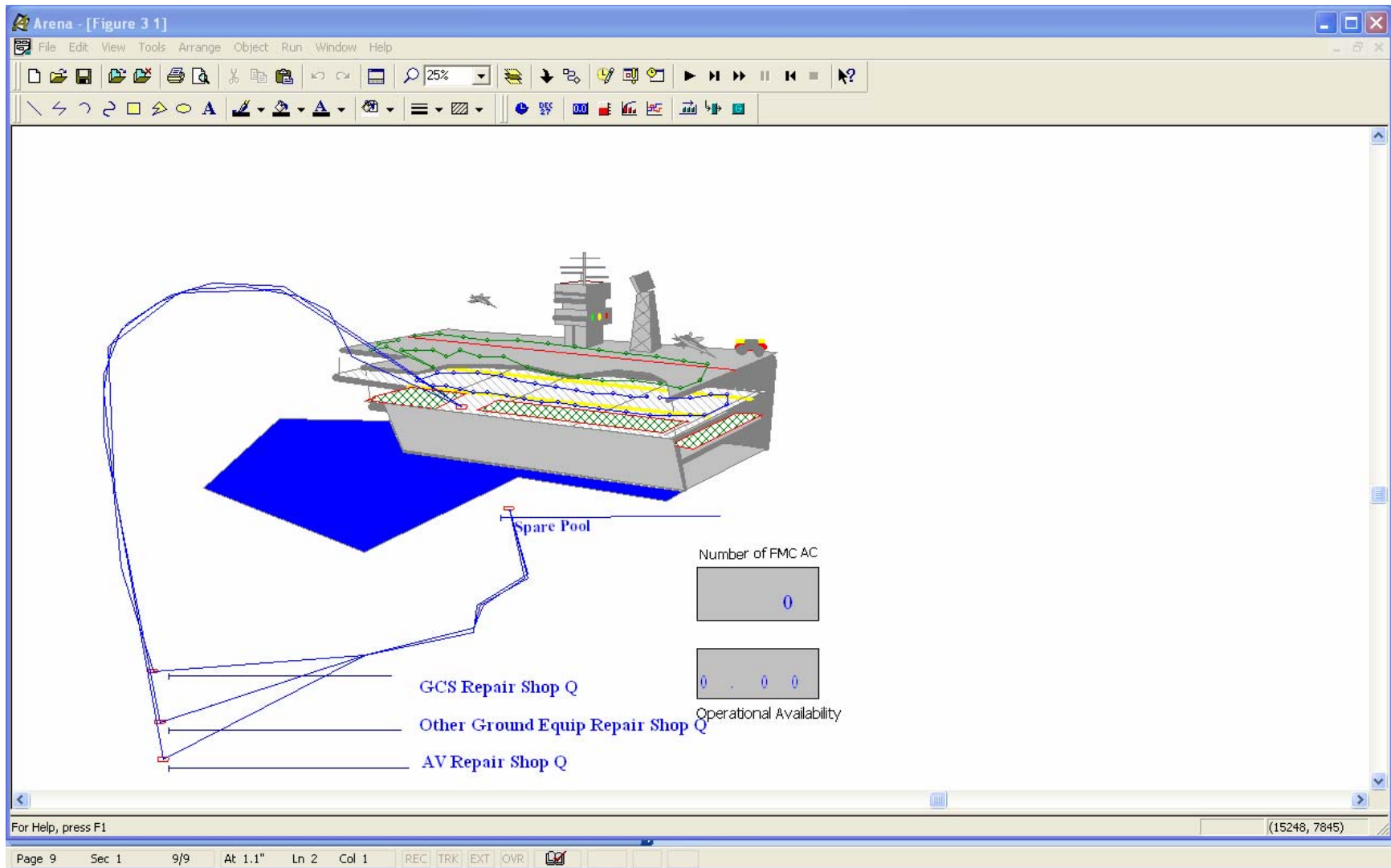


Figure 3.1: Scenario 3 Simulation Model

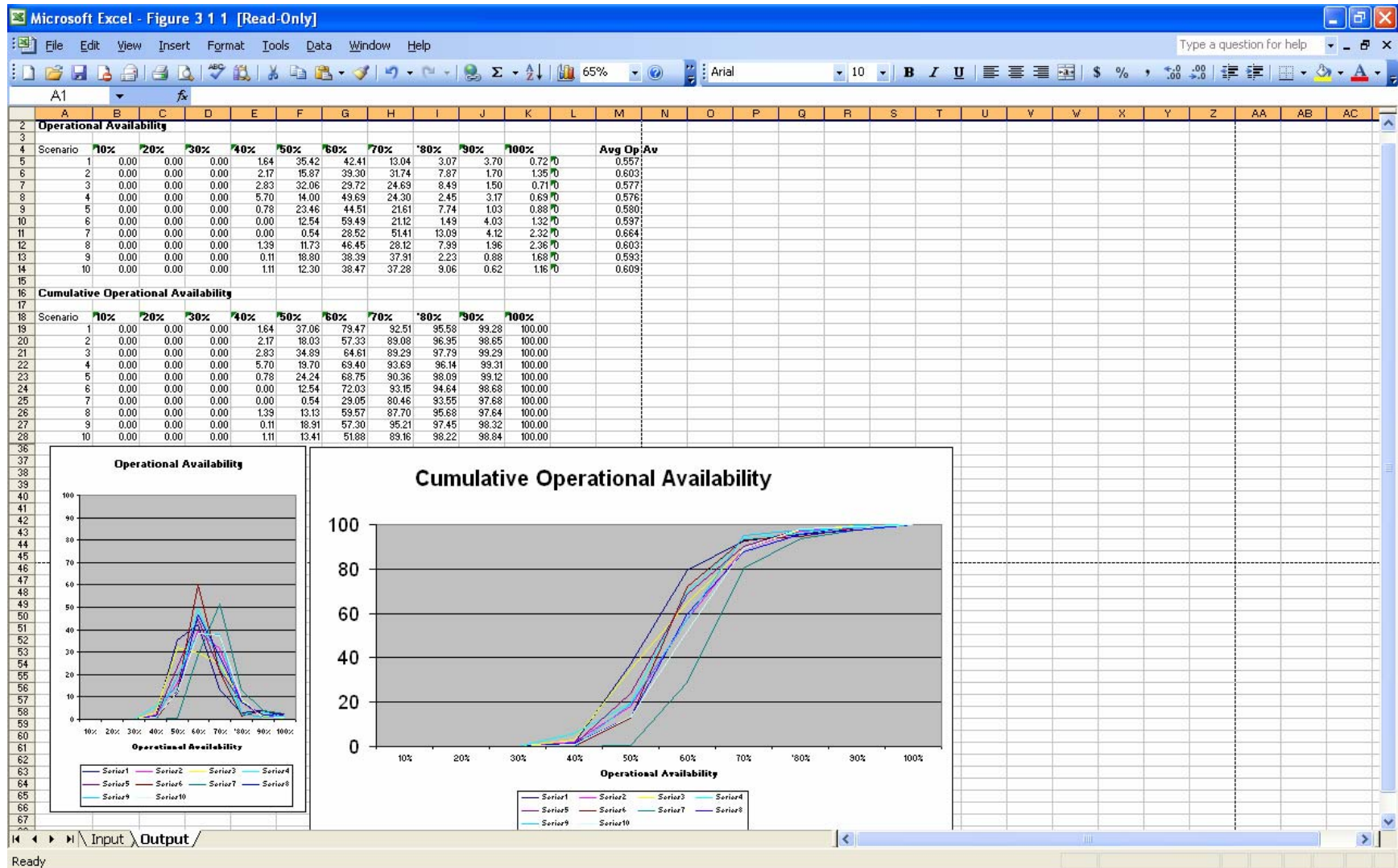


Figure 3.1.1: Scenario 3 Simulation Spreadsheet

APPENDIX C. LIST OF ABBREVIATIONS AND ACRONYMS

λ	lambda
ACAT	Acquisition Category
ACC	Aircraft Controlling Custodians
AE	Age Exploration
A _o	Operational Availability
AV	Air Vehicle
AVHours	Air Vehicle Hours
AW	Acquisition Window
BCA	Business Case Analysis
BDA	Battle Damage Assessment
COMNAVAIRFOR	Commander, Naval Air Force
D Level Maintenance	Depot Level Maintenance
DoD	Department of Defense
DPG	Defense Planning Guide
DTG	Date/Time Group
E	Enlisted
ECU	Environmental Control Unit
FCA	Field Cognizant Activities
FIRST	F/A-18E/F Integrated Readiness Support Team
FLIR	Forward Looking Infrared
FY	Fiscal Year

GAO	General Accountability Office
GCS	Ground Control Station
GDT	Ground Data Terminal
GPS	Global Positioning System
HMMWV	High Mobility Multipurpose Wheeled Vehicle
Hrs	Hours
IG	Inspector General
I Level Maintenance	Intermediate Level Maintenance
IMA	Intermediate Maintenance Activity
K	Number of Components
KPP	Key Performance Parameters
LCC	Life Cycle Cost
LOS	Line of Sight
L/R	Launch/Recovery
MDT	Maintenance Down Time
MMP	Modular Mission Payload
MTBF	Mean Time Between Failure
MTBM	Mean Time Between Maintenance
MWIR	Medium Wave Infrared
NAMP	Naval Aviation Maintenance Program
NAVAIR	Naval Air (Systems Command)
NAVICP	Naval Inventory Control Point
NWCF	Naval Working Capital Fund

OEM	Original Equipment Manager
O Level Maintenance	Operational Level Maintenance
O&M	Operations and Maintenance
OPTEMPO	Operational Tempo
OSD	Office of the Secretary of Defense
PBL	Performance Based Logistics
PGCS	Portable Ground Control Station
PGDT	Portable Ground Data Terminal
PM	Program Manager
POL	Petroleum, Oil, & Lubricants
POP	Plug-In Optical Payload
QDR	Quadrennial Defense Review
RCM	Reliability Centered Maintenance
RDT&E	Research, Development, Testing and Evaluation
RFI	Ready For Issue
ROI	Return On Investment
RSTA	Reconnaissance, Surveillance, and Target Acquisition
RVT	Remote Video Terminal
SDLM	Standard Depot Level Maintenance
SE	Support Equipment
TALS	Tactical Automatic Landing System
TAT	Turn Around Time

TD	Technical Directive
T	Time
TLCC	Total Life Cycle Cost
TLCSM	Total Life Cycle Systems Management
TOC	Total Ownership Cost
UAV	Unmanned Air Vehicle
UPS	Uninterruptible Power Supply
VTUAV	Vertical (Take-Off and Landing) Tactical Unmanned Air Vehicle

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